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An analysis of the first fifteen years of the Department of Defense framework for Unmanned Ground Systems

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MBA PROFESSIONAL REPORT

AN ANALYSIS OF THE FIRST FIFTEEN YEARS OF THE DEPARTMENT OF DEFENSE FRAMEWORK FOR UNMANNED GROUND SYSTEMS

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December 2014

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The Unmanned Ground Vehicle (UGV) program traces its roots back to Desert Shield and Desert Storm. At that time, warfighters observed the use of Unmanned Aerial Vehicles and recognized the potential for their ground use. Literature supporting this research focuses on UGV history, the Sigmoid Curve, associated push and pull factors, and the Department of Defense (DOD) Acquisition Strategy. DOD UGV master plans, which are used to conduct comparative analyses of programs, changes, and trends from year to year, examine the cost, schedule, and performance of all programs from 1991 to 2004. This research focuses on experienced schedule overruns, slippage, and the examination of characteristics leading to system success. This research also explains the relationship between push and pull factors and further outlines the evolution of UGV program requirements based on global conflicts and various mission types. This research clearly indicates that UGVs are created for force protection more than any other warfighting function.

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AN ANALYSIS OF THE FIRST FIFTEEN YEARS OF THE DEPARTMENT OF DEFENSE FRAMEWORK FOR UNMANNED GROUND SYSTEMS

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

AAP	Abbreviated Acquisition Program
ACAT	Acquisition Category
ADM	Advanced Development Model
AI	Artificial Intelligence
AKO	Army Knowledge Online
ALV	Autonomous Land Vehicle
AOA	Analysis of Alternatives
AOE	Advanced Ordnance Excavator
AP	Anti-Personnel
APOBS	Anti-Personnel/Obstacle Breaching System
APUC	Acquisition Program Unit Cost
ARC	Active Range Clearance
AROMS	Active Range Ordnance Mapping System
ARS	Advanced Robotic Systems
ARTS	All-Purpose Robotic Transport System
ARTS-FP	All-Purpose Robotic Transport System Force Protection
ART STO	Armed Robotic Technology, Science & Technology Objective
ARV	Armed Robotic Vehicle
ASD	Advanced System Development
ATD	Advanced Technology Demonstration
ATV	Autonomous Tow Vehicle
BFV	Bradley Fighting Vehicle
BIP	Blow in Place
BTA	Best Technical Approach
BUGS	Basic UXO Gathering System
C2	Command and Control
C4I	Command, Control, Communications, Computers, and Intelligence
CAT	Crew Integration and Automated Test Bed
CBO	Congressional Budget Office

CBRNE	Chemical, Biological, Radiological, Nuclear, and High-Yield Explosives
COBRA	Combined Operations Battlefield Robotics Asset
COEA	Cost and Operation Effectiveness Analysis
COEE	Concept of Employment Evaluation
CONUS	Continental United States
CRK	Common Robotic Kit
CRS	Common Robotic System
CRS	Congressional Research Service
CTD	Concept and Technology Demonstrations
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DEMVAL	Demonstration and Validation
DOE	Department of Energy
DT&E	Developmental Test & Evaluation
DTIC	Defense Technical Information Center
EMD	Engineering, Manufacturing & Development
EOD	Explosive Ordnance Disposal
EUT&E	Early User Testing and Evaluation
EVTC	Engineer Vehicle Teleoperation Capability
FCS	Future Combat Systems
FOB	Forward Operational Base
F-P	Force Protection
FRP	Full Rate Production
FTUV	Family of Tactical Unmanned Vehicles
FUE	First Unit Equipped
FY	Fiscal Year
FYDP	Future Years Defense Plan
GAO	Government Accountability Office
GSTAMIDS	Ground Standoff Mine Detection System
HMMWV	High Mobility Multi-Wheeled Vehicle
HRI STO	Human-Robot Interaction, Science & Technology Objective

ICD	Initial Capabilities Document
IED	Improvised Explosive Device
IFV	Infantry Fighting Vehicle
IMP	Intelligent Mobility Program
IOC	Initial Operational Capability
IOT&E	Initial Operational Test & Evaluation
IPR	In-Progress Review
IVMMD	Interim Vehicle-Mounted Mine Detector
JAUGS	Joint Architecture for Unmanned Ground Systems
JAUS	Joint Architecture for Unmanned Systems
JCAD	Joint Chemical Agent Detector
JCIDS	Joint Capabilities Integration Development System
JGRE	Joint Ground Robotics Enterprise
JROC	Joint Requirements and Oversight Council
JRP	Joint Robotics Program
JRPMP	Joint Robotics Program Master Plan
JUONS	Joint Urgent Operational Need Statement
KPP	Key Performance Parameters
LERS	Light-Weight Equipment Reconnaissance System
LOS	Line-of-Sight
LRIP	Low Rate Initial Production
LVOSS	Light Vehicle Obscurant Smoke System
MCD	Mine, Countermine, and Demolitions
MCM	Mine Counter Measure
MDA	Milestone Decision Authority
MDARS	Mobile Detection Assessment Response System
MDARS-E	Mobile Detection Assessment Response System-Exterior
MDARS-I	Mobile Detection Assessment Response System-Interior
MH/K	Mine Hunter/Killer
MNS	Mission Needs Statement
MOA	Memorandum of Agreement
MOS	Military Occupational Specialty

MOUT	Military Operations in Urban Terrain
MPM	Mission Payload Module
MPRS	Man-Portable Robotic Systems
MSR	Military Supply Route
MTOE	Military Table of Organizational Equipment
MTRS	Man Transportable Robotic System
MULE	Multifunction Utility/Logistics Equipment
NGEODRCV	Next Generation EOD Remote Controlled Vehicle
NG-FPRS	Next Generation-Force Protection Robotics System
NBC	Nuclear, Biological, Chemical
NPS	Naval Postgraduate School
NUSE2	National Unmanned Systems Experimentation Environment
O&M	Operations and Maintenance
O&O	Operational and Organizational
OCU	Operator Control Unit
ODIS	Omnidirectional Inspection System
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OT&E	Operational Test & Evaluation
PM	Program Manager
POM	Program Objective Memorandum
PSEMO	Physical Security Equipment Management Office
PSVM	Performance Specifications Verification Model
PUCA	Pick Up and Carry Away
R&D	Research & Development
RACS	Robotics for Agile Combat Support
RATV	Robotic All-Terrain Vehicle
RAVENS	Robotic Acquisition through Virtual Environments & Networked Simulations
RCSS	Robotic Combat Support System

RCT	Remote Control Transporter
RDT&E	Research, Development, Testing, and Evaluation
RECORM	Remote Control Reconnaissance Monitor
REDCAR	Remote Detection, Challenge, and Response System
REV	Robotic Excavation Vehicle
REVS	Robotic Excavation Vehicle System
RF	Robotic Follower
ROCS	Robotic Ordnance Clearing System
ROND	Remote Ordnance Neutralization Device
RONS	Remote Ordnance Neutralization System
RRR	Rapid Runway Repair
RSJPO	Robotic Systems Joint Project Office
RSTA	Reconnaissance, Surveillance, and Target Acquisition
SARGE	Surveillance and Assessment Robot for GI Enhancement
SBIR	Small Business Innovative Research
SC	Strategic Computing
S-Curve	Sigmoid Curve
SDD	System Development and Demonstration
SME	Subject Matter Expert
SOF	Special Operations Forces
SOP	Standard Operating Procedure
SRS	Standardized Robotic System
STV	Surrogate Teleoperated Vehicle
TMAP	Teleoperated Mobile All-Purpose Platform
TOA	Tradeoff Analysis
TOD	Tradeoff Determination
TOV	Teleoperated Vehicle
TRADOC	Training and Doctrine Command
TRL	Technology Readiness Level
TSWG	Technical Support Working Group
TTB	Technical Test Bed
TTPs	Tactics, Techniques, and Procedures

TWP	Tactical Warfare Program
TUGV	Tactical Unmanned Ground Vehicle
TUV	Tactical Unmanned Vehicle
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UGS	Unmanned Ground Systems
UGV	Unmanned Ground Vehicle
UGVMP	Unmanned Ground Vehicle Master Plan
UGVTEE	Unmanned Ground Vehicle Technology Enhancement and Exploitation
URBOT	Urban Robot
UMS	Unmanned Maritime Systems
U.S.	United States
USAF	United States Air Force
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USG	United States Government
USMC	United States Marine Corps
USN	United States Navy
UXO	Unexploded Ordnance
VT	Vehicle Teleoperation
VTC	Vehicle Teleoperation Capability
XUV	Experimental Unmanned Vehicles

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I. INTRODUCTION

Core requirements that led to the creation of the Unmanned Ground Vehicle (UGV) program in 1990 are unavailable, but reasonable assumptions can be made based on programs presented in the 1991 master plan. According to the 1991 master plan, there are five potential payoffs of UGVs:

1. reduced risk to human life and increased operational flexibility in combat or other hazardous environments,

2. economy of manpower or reduced costs in operations done repetitively (e.g., logistics) where manpower savings more than offset investments in equipment,

3. reduced training costs and increased training realism,

4. improved performance where automated systems either perform better than humans or eliminate the system compromises required by human physiological limits (creature comfort, fear, fatigue, vibration, etc.), and

5. force multiplication where operators with UGVs bring substantially more capability to bear than would be possible by individual troops without UGVs. (Department of Defense [DOD], 1991, p. 2)

Based on these potential payoffs, the initial uses for unmanned ground systems were created. "There are a variety of potential applications of robotics to land operations that can increase efficiency and safety. These, include reconnaissance, target engagement, logistics, runway repair, minefield detection and neutralization, explosive ordnance disposal, physical security, and operations in contaminated environments" (DOD, 1991, p. 3). The program continued to expand, and under the 1991 master plan, three programs were established. The three programs are the Tactical Unmanned Ground Vehicle (TUGV) program for Reconnaissance, Surveillance and Target Acquisition (RSTA) mission, the Remote Ordnance Neutralization Device (ROND) program for Explosive Ordnance Disposal (EOD) technicians, and the Rapid Runway Repair (RRR) program for the creation of runways in full-spectrum operations against a large-scale military threat.

The overall UGV program advanced as a result of operations Desert Shield and Desert Storm. Warfighters observed the use of Unmanned Aerial Systems (UASs) in the conflicts and these likely triggered ideas for further use of unmanned systems on the ground.

A. PURPOSE OF THE RESEARCH

The purpose of this research is to provide the reader with an analysis of how the UGV program evolved over a 14-year period. It is important to understand the changes observed with each new master plan and to identify trends and challenges that are common and relevant to the UGV community and other similar DOD programs. When dealing with advanced technology development, it was necessary to observe the impact of funding on technology development and program schedule expectations. The research considers supply and demand factors as well as the impact of success on a DOD program or system. The research further aims to manage technology performance expectations and explain why certain programs achieve full rate production and others remain in a perpetual state of research and development (R&D). For programs that are rich in technological complexity, the research offers potential considerations to achieve program success.

B. RESEARCH QUESTION

This paper focuses on answering the following questions:

1. Do UGS programs historically experience cost and schedule overrun, and if so, why?

2. Are there characteristics that lead to the successful fielding of UGS or that prevent a system from achieving full rate production?

3. What effect do political and global security events have on programs within the UGV portfolio?

4. What role do push and pull factors play in the success of a UGV program?

C. BENEFITS OF THE RESEARCH

This research provides a historical analysis of the first 14 years of the unmanned grounds systems program, which can assist in managing expectations for cost, schedule and performance of highly complex technology-based programs in the DOD. It also helps explain the fine balance between push and pull factors and how both factors are required before integration of new technology.

D. LIMITATIONS OF THE RESEARCH

Prior literature and relevant DOD documents on this topic are limited, affording limited analysis. The research does not include classified information, which could reveal significant trends not identified in this research project.

E. SCOPE AND RESEARCH METHOD

A comparative analysis was conducted on all DOD Unmanned Ground Systems master plans from 1991 to 2004. A side-by-side comparison of documents displayed changes to program schedules and funding that led to findings within the research. A focus on requirements and user demand led to the results of this research.

F. ORGANIZATION OF THE RESEARCH REPORT

Chapter II examines prior literature written on the topic of UGS, the history of UGS, how the Sigmoid Curve (S-Curve) is relevant to the research and the DOD acquisition strategy for UGS. Chapter III discusses the methods of data collection used and the analysis conducted to arrive at the results presented in the research paper. Chapter IV examines all available DOD Unmanned Ground Systems master plans from 1991 to 2004. Further analysis of the PackBot and Talon robots is included as a case that adds unique value and concludes with the intervention of DARPA on the UGV program in 2004. In the final section, Chapter V, the overall research is summarized, results are concluded, and future research is recommended.

G. SUMMARY

The overall UGV program grew significantly in a 14-year period. New programs and systems were created based on current and perceived threats. Most, if not all, of current new programs and systems derive from programs and technologies of the past. UGV development is an evolutionary approach, but the complex technology has its limitations. Achievement of highly autonomous operations will require major technological breakthroughs, whose future benefits far outweigh any possible obstacles.

II. LITERATURE REVIEW

A. INTRODUCTION

During the conflicts in Iraq and Afghanistan, the U.S. Army has seen significant growth in the procurement and application of unmanned ground systems (UGSs) to enhance mission capabilities and to protect service members on the battlefield. The supporting service members are capable of conducting reconnaissance, surveillance, explosive ordnance disposal (EOD)/improvised explosive device (IED) detection, transportation of troop gear, and movement of service members around the battlefield. Advances in unmanned systems technology, which enhance mission capability and protection of service members, took many years of research and development to come to fruition. Therefore, to understand the technological advances on the modern battlefield, it is necessary to examine early research efforts which have made these advances possible.

In this literature review, early research efforts, methods of determining technology development (the S-curve), and the implementation of unmanned ground systems throughout the DOD are examined annually in the UGV master plans. It is important to recognize that minimal research was conducted on the analysis of the UGS program, which is the primary focus of this thesis. The majority of this research material came from congressional and DOD reports, because there is not an abundance of information published in scholarly journals. Comparative analysis of the UGV master plan is used to discuss trends observed in the first 15 years of UGS and to present considerations for future UGS programs and other highly advanced, technology-based programs.

B. BRIEF HISTORY

A brief history of UGS systems requires the reader to look back over 40 years ago to the 1960s to gain perspective of how early robotic systems evolved over time and how their development influenced modern-day mobile robotics and unmanned military applications. One of the first examples of major robot development, Shakey, was developed by the Defense Advanced Research Projects Agency (DARPA). According to

Gage (1995), “Shakey was a wheeled platform equipped with steerable TV camera, ultrasonic range finder, touch sensors, connected via an RF link to its SDS-940 mainframe computer that performed navigation and exploration tasks” (p. 2). Shakey is designed to be fully autonomous and receive commands given by a human operator to move objects around the lab environment. The Shakey mobile robot is designed to be autonomous, but never achieved its operational goal and therefore is considered a failure. However, the Shakey project identified technical deficiencies, established functional and performance baselines, and aided in the artificial intelligence (AI) research areas of planning, vision, and natural language processing (Gage, 1995). The key technological lessons learned from the development of Shakey are the advances in technology and components discovered from this particular system, which can be researched and developed further, and the technologies utilized in future robotic systems.

Nearly 20 years later, in the 1980s, DARPA refocused its studies from the Shakey Project and understanding of AI and created a new program called the Autonomous Land Vehicle (ALV). Under this new project, DARPA’s Strategic Computing (SC) program’s goal “was to provide a realistic task environment for technology research” (Gage, 1995, p. 3). DARPA was able to use previously discovered technologies and knowledge from the Shakey project, build upon them, and create the ALV, which was an autonomous platform built on an “8-wheel hydrostatically-driven all-terrain vehicle capable of speeds of up to 45 mph on the highway and up to 18 mph on rough terrain” (Gage, 1995, p. 3). The ALV program used technologies, applications, and an integrated project team, which consisted of the integration contractor Martin-Marietta (merged with Lockheed Corporation in 1995) and functional components provided by other ARPA-funded technology developers such as Hughes Research Lab, Carnegie-Mellon University, and the University of Maryland (Gage, 1995). Various developers and collaboration among government research laboratories, the technology industry, and academia enabled projects such as Shakey and the ALV to develop prototypes and demonstrate applications that had an impact not only in the civilian sector, but the military as well.

The prospect of utilizing autonomous applications for military purposes created opportunities for the market to develop systems, which could provide unmanned ground vehicle applications for military commanders. These systems could provide commanders with Reconnaissance, Surveillance, and Target Acquisition (RSTA) capabilities on the battlefield without risking the lives of service members. Thus in the mid- to late-1980s, the DOD invested in programs and applications similar to what is seen on the modern battlefield today (Gage, 1995).

Programs and prototypes such as the Teleoperated Vehicle (TOV), Teleoperated Mobile All-Purpose Platform (TMAP), Tactical Unmanned Ground Vehicle (TUGV), Surveillance and Assessment Robot for GI Enhancement (SARGE), and Gecko were all developed to provide the military commander with the capability of not putting service members in harm's way.[1]

C. THE S-CURVE

As part of this research and analysis, it is important to understand where technology and the innovation to create advances in robotics come from. As discussed in Section B, Brief History, the beginning of the robotics evolution of unmanned systems began with the Shakey and Autonomous Land Vehicle (ALV) programs. The S-Curve is a visual representation (see Figure 1) of how long it takes a new technology to be adopted from innovation, to adoption, then to "taking off" and finally "leveling off" when the technology is considered mature.

In order to conduct analysis on the S-Curve, it is important to understand the drivers of innovation, which are demand-pull and supply-push. According to Geroski (2003), demand-pull is when a new innovation is pulled out of the lab and allows innovators to develop a product or service that is specific to meet customer requirements and can be released into the market.

[1] For further reading and more detailed information on each program/prototype specification, reference the article "UGV History 101: A Brief History of Unmanned Ground Vehicle (UGV) Development Efforts," written by Douglas W. Gage (1995).

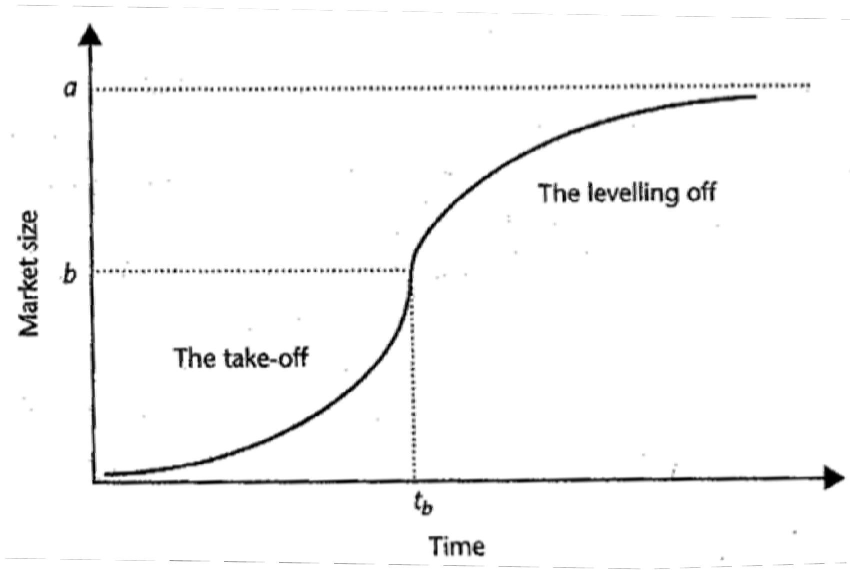

Figure 1. S-Curve representation of the path technology takes from innovation, through adoption, to maturity (from Geroski, 2003)

According to Geroski, supply-push is when a new innovation is “pushed” out to the market and occurs when existing technology experiences a breakthrough and then branches out into a new technology trajectory (see Figure 2). Geroski stated, “A technology trajectory is a sequence of innovations which follow each other, all drawing on the same basic scientific or engineering principle(s), each drawing from and then contributing to a cumulatively increasing body of knowledge and expertise” (Geroski, 2003, p. 39). When looking at the evolution of ground robotics technology, it can be deduced that it is a supply-push to the market.

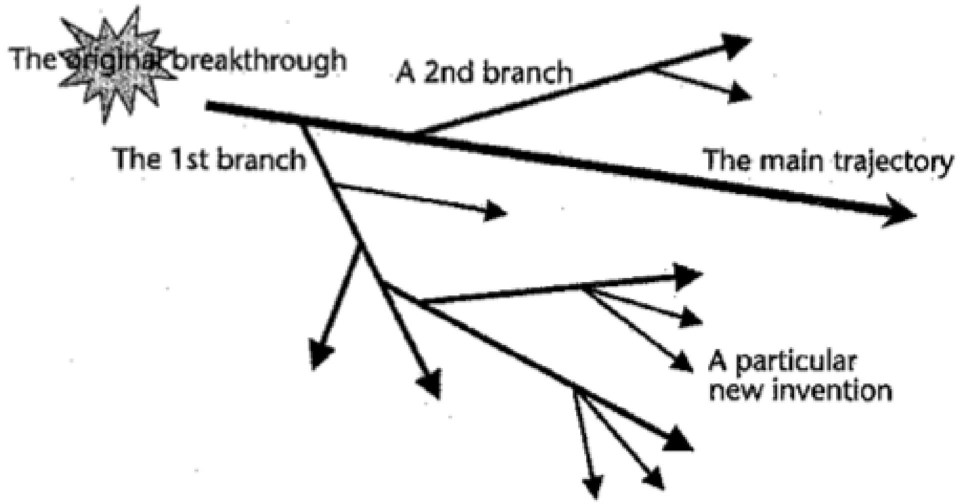

Figure 2. Technology Trajectory (from Geroski, 2003).

The S-Curve literature is useful to help the reader understand where UGS stand today in terms of technology maturation. This becomes more apparent in later sections of this paper.

D. DEPARTMENT OF DEFENSE ACQUISITION STRATEGY

With the development of new technologies and the perception of a lack of coordinated research and development effort, in 1989, Congress mandated in the Defense Appropriation Act, “The Deputy Secretary of Defense for Tactical Warfare Programs should assume the role of focusing these technology efforts … and should submit a master plan by May 1, 1989 addressing Department initiatives to advance joint robotics programs” (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)], Portfolio ... Robotics Enterprise, 2006, p. 5). This act created one robotics program called the Joint Ground Robotics Enterprise (JGRE).

UGS has proven itself effective in current and past operations such as Operations Desert Shield/Storm, Operation Enduring Freedom-Afghanistan (OEF-A), Operation Iraqi Freedom (OIF), and peacekeeping missions in Bosnia. During these operations, UGS saved lives and provided crucial support capabilities to ensure the commander on the ground could successfully accomplish the mission (OUSD[AT&L], Portfolio ... Robotics Enterprise, 2006, p. 3). The UGS used during these conflicts provided service members with the capability to exploit IEDs, provide reconnaissance, detect and dispose of explosive ordnance and ensure force protection of the warfighter while conducting operations (OUSD [AT&L], Portfolio ... Robotics Enterprise, 2006, p. 3).

As discussed in Section B, the ability to provide enhanced UGS capabilities began with industry leaders in robotics collaborating with each other to conduct research and then develop new technologies to ensure new applications could be created and improved upon. According to the 2006 *Report to Congress*, the main strategy for the development of ground robotics is a joint collaboration among the military services, industry, and academia. To be more cost effective and better stewards of the taxpayer's dollar, the collaborative strategy directed the government to

> leverage funding, share technological advancements, accelerate research, development and fielding of solutions, promote synergy across the DOD unmanned systems (UMS) community, and to promote interoperable systems … teaming initiatives focus on basic research in science and technology areas likely to product robotic technology breakthroughs. (OUSD [AT&L], Portfolio ... Robotics Enterprise, 2006, p. 4)

In addition to directing the coordinating activities, the National Defense Authorization Act for Fiscal Year (FY) 2006, Sec. 261 requested an update to the NDAA for FY01, which included a goal for the military to have one-third of its operational ground combat vehicles unmanned (Moreau & Nugent, 2005). With the advantage of hindsight, this goal appeared to be very aggressive and perhaps too optimistic, as it is now 2014 and the military is not close to meeting these numbers. This goal will need to be reviewed and a determination made of when or if the military will or can meet this objective.

Future Unmanned Ground System (UGS) programs may be affected by the current budget-constrained environment. Due to the inherent risk of deploying service members and putting them in harm's way to engage state and non-state actors, it is assumed that the requirements for further research and development of new and emerging technologies will either remain constant or increase over time. The justification for this assumption is the pending reductions in the military force structure numbers (U.S. Army) based on proposed budget requests. The proposed reduction focuses on reducing the number of Soldiers from its current strength of 520,000 to approximately 440,000 active military, which is a delta of 80,000 Soldiers (Simeone, 2014). Further analysis is required to determine if the benefits of having a more automated or robotically enhanced military is conducive to the U.S. military meeting National Security Interests and Objectives.

Advances in technology and combat capabilities to enhance the commander's capabilities are available, but it appears there is a disconnect between linking UGS capabilities and incorporating them with the organic structure of the current military force. This study assumes that only EOD and Engineer military units understand and have taken advantage of having UGS systems, developed doctrine which directs the unit command on "how to" employ EOD and Engineer UGS, and is part of its Modified Table of Organization and Equipment (MTOE). According to the U.S. Army Quartermaster (2014) homepage, "The MTOE document is a modified version of a TOE approved by Headquarters, Department of the Army that prescribes the unit organization, personnel and equipment necessary to perform an assigned mission in a specific operational or geographical area" (Brown, 2000).

Other combat and combat service support units could take advantage of the UGS programs, but without direction from U.S. Army Training and Doctrine Command (TRADOC), how long will it take for these systems to become organic to the unit? The U.S. Army attempted to do this with the Future Combat System (FCS) program, but the program was unsuccessful and subsequently cancelled due to cost overruns and schedule slippage.

Through comparative analysis of the UGV road maps, a visual representation of the current state of the unmanned ground systems (UGS) program over the past 14 years (1991–2004) is provided in Chapter IV. Based upon extensive research of the data retrieved from the Robotics System Joint Project Office (RSJPO) intranet, it was determined this type of analysis was not conducted and the results will provide DOD leadership with a snapshot of the UGS environment.

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III. METHODOLOGY

From 1991 to 2004, the DOD published master plans to explain the current state of UGS in the U.S. Army and show cost, schedule, and performance of each program. In this thesis, the comparative analysis method of the data provided in the master plans is used to conduct a year-to-year analysis of each program and observe the overall performance of each UGV program in the time period specified. All programs in each year's plans are discussed, but this thesis focuses on, tracks, and summarizes only five programs throughout the entire research project. The decision to track these programs is based on their consistency and traceability throughout the years analyzed. The five programs include Tactical Unmanned Ground Vehicles (TUGV), Remote Ordnance Neutralization System (RONS), Robotic Excavation Vehicle (REV), Engineer Vehicle Teleoperation Capability (EVTC), and Mobile Detection Assessment Response System—Exterior/Interior (MDARS-E/I). Analyzing the master plans allows the observation of trends in schedule and funding which may help prevent future budget and schedule challenges in similar programs.

Limited research on this topic resulted in the utilization of unique sources for the literature review portion of this thesis. Scholarly and non-traditional academia sources are evaluated, which aids in understanding the subject and assists in preparing the literature review. This data was collected from NPS, the U.S. Army War College, the Defense Technical Information Center (DTIC), the U.S. Army's website for publications and doctrine, the Robotics Systems Joint Project Office (RSJPO), the Defense Advanced Research Projects Agency (DARPA), the Congressional Budget Office (CBO), and Congressional Research Service (CRS).

This reference material focuses on the current state of UGS, its history, research, and development (R&D), and implementation in the DOD. Other literature collected describes the U.S. Army acquisition strategy from program inception through present day and addresses the notion of implementing such a drastic technology change into the force. A portion of the data collection focused on the challenges the U.S. Army faces with the integration of UGS into the force and the current U.S. Army doctrine and military tables of organizational equipment (MTOE).

This thesis reviews U.S. Army doctrine, available through multiple sources such as the Army Knowledge Online (AKO) website, which provides information about various military occupational specialties that utilize UGS in their operations (http://armypubs.army.mil/doctrine/index.html). This search of doctrine began with explosive ordnance disposal (EOD), combat engineer, and chemical, biological, radiological, nuclear and high-yield explosives (CBRNE) units to determine if doctrine existed in these career fields. The search was then expanded into special operations forces (SOF) and conventional forces. Lastly, the search was expanded into weapons doctrine to determine if unmanned systems exist. MTOEs were collected from the referenced career fields to determine if UGS is listed as mandatory items on unit property books.

Master plans, road maps, books, journals, and other online sources were utilized to better understand the current UGS environment and development of UGS technology. Master plans and technology development were examined chronologically to observe advancements and challenges new to a master plan or those that were repetitive year after year. Schedule figures and funding tables were created for key programs, which cover five-year periods from 1991 to 1995, 1996 to 2000, and 2001 to 2004. An overall schedule and funding figure was also created, which examines key programs from 1991 to 2004. Lastly, a quantitative analysis of the DOD budget against the UGV program budget was conducted to determine if a correlation exists and if future budget trends are predictable.

The Sigmoid-Curve (S-curve) model allows examination of the UGS industry and allows an educated estimate about where the industry lies on the S-Curve today. Literature was further utilized as a means of analyzing exploration of new technology versus exploitation of existing technology. Push and pull factors were examined for the key systems in the UGV program to help explain why some systems flourish and are delivered to warfighters and other simply remain in a perpetual state of R&D.

Master plans, road maps, and congressional budgetary documents were used to analyze the UGS program schedules and budgets and their effect on the program. Funding allocated to R&D, procurement, and individual systems from the beginning of a program were examined as well as changes to the schedules and funding over time. The researchers seek to determine whether there were trends in the program related to budget uncertainty and if smaller Acquisition Category (ACAT) III programs tend to go over budget and schedule or are more stable due to their small scope. Another goal is to examine the overall growth of the program in regard to dollars and numbers of systems. This information is used to determine if there is a correlation between specific events in time and UGV program funding, or if the program was gaining popularity within the DOD and receiving a larger portion of the budget because of the demand for UGS. The same sources are utilized to examine the U.S. military's cultural feelings in regard to UGS. The purpose of this was to determine if the organizational culture is a barrier to success for UGS due to factors such as pride, status, and glory on the battlefield or a basic lack of trust in UGS. Cultural beliefs are compared with the amount of systems currently fielded by various branches and communities in the Army to determine if the presence of systems has an effect on cultural acceptance.

All master plans are assembled in chronological order to analyze various factors. The goal is to compare what was planned in each master plan to what was actually accomplished over time. The researchers investigate what was implemented into various units, what was cancelled, and the reasons for success and failure of specific systems. All of the information analyzed is used to present interesting trends among UGS programs, which may be practical for future UGS program consideration or for other highly advanced technology programs in the DOD that are similar to UGS technology.

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IV. HISTORICAL ANALYSIS OF ROAD MAPS (1991–2004)

The unfolding figure (see Figure 3) for UGVs provides a visual representation of the requirements rationale over time. From 1991 to 2004, the United States was involved in six conflicts, which is depicted by the red cylindrical time line at the top of the page in Figure 3. From the conflicts, requirements are identified and highlighted by the yellow rectangles below the time line. To satisfy requirements, UGV solutions were developed and are highlighted by the green ovals. In 1991, only three programs existed to satisfy some of the capability gaps (CAPGAP). As the UGV program progressed, new programs emerged to satisfy the CAPGAP. From the original programs in 1991, new programs and systems emerged to satisfy warfighter needs based upon the current threat.

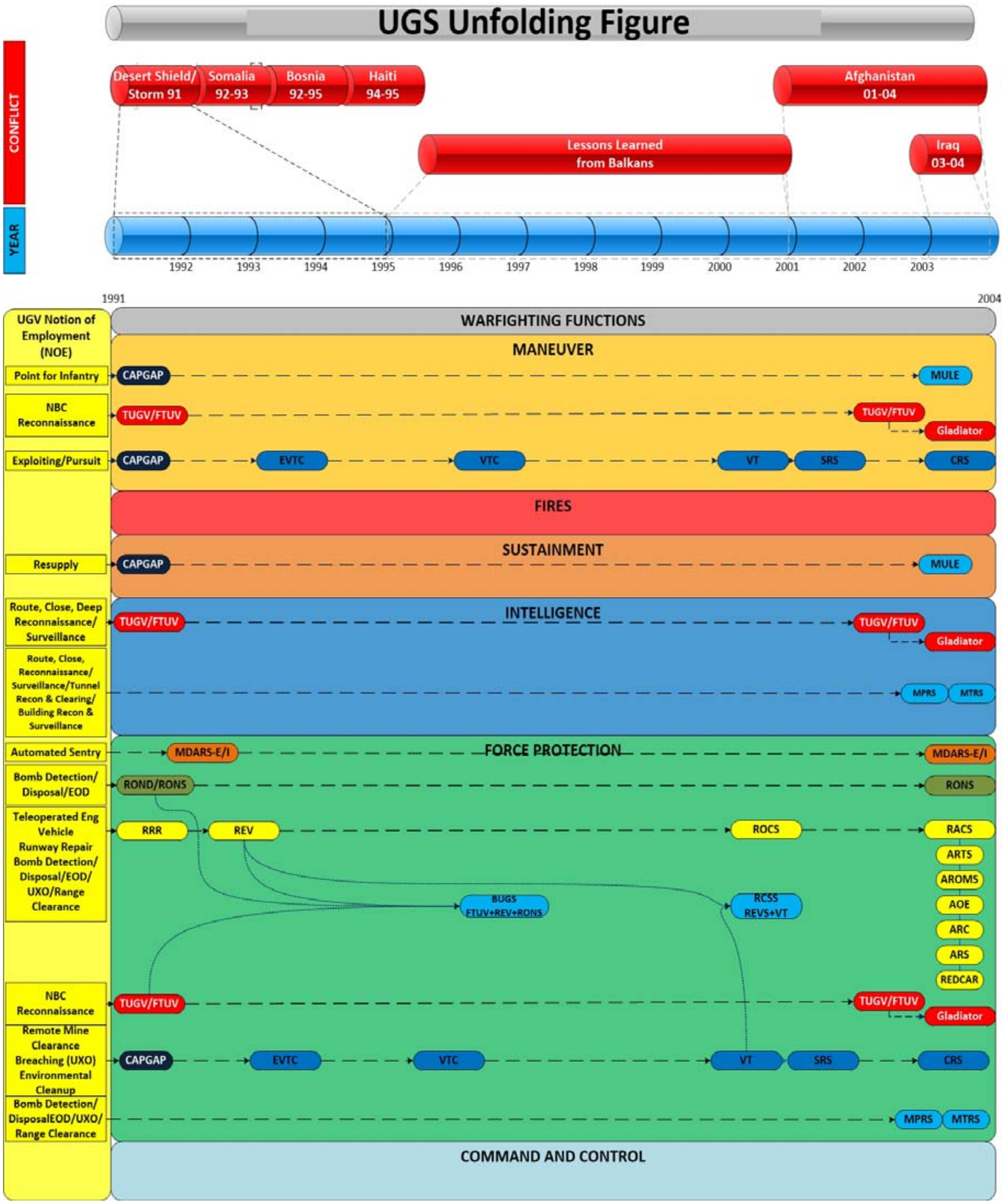


Figure 3. UGS Unfolding Figure with Notion of Employment

A. 1991 MASTER PLAN THROUGH 1995 MASTER PLAN

In Section A, the research identifies each UGV program mentioned in the master plans from 1991 to 1995, and conducts a comparative analysis of the schedule and funding of each program. The purpose of the research is to identify adjustments to the overall schedule and funding while examining program growth in terms of new systems and UGV program funding. The section concludes with an analysis of schedule and funding from 1991 to 1995 on programs that continued through the years observed.

1. 1991 Unmanned Ground Vehicle Master Plan

The 1991 unmanned ground vehicle master plan (UGVMP) is the first formalized document that presents a DOD level plan and strategy for UGVs. Its main purpose is to "provide a single, integrated DOD document that lays out the strategy for introducing supervised robotic vehicles into our forces and the plan for development and acquisition of unmanned ground vehicle systems" (DOD, 1991, p. 2). The plan, which was created in response to recent combat operations during Desert Shield and Desert Storm, also addresses unmanned systems utilized during combat operations, primarily in the air. The requirements that led to the solution for that year are shown in Table 1.

Table 1. Requirements Articulation 1991 UGV Master Plan

1991
Requirement
Explosive Ordnance Disposal
Logistics
Minefield Detection & Neutralization
NBC operations on the battlefield
Physical Security
Reconnaissance
Runway Repair
Target Engagement
Threat/Conflict
Cold War (Soviet Union 1945-1991)
Desert Shield/Storm - Iraq (1990-1991)
UGV Solution
Tactical Unmanned Ground Vehicle (TUGV)
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
NBC Detection and Laser Designation
Rapid Runway Repair (RRR)/Robitic Evacuation Vehicle(Rev) (Initiated 1990)
Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas)
Remote Ordnance Neutralization Device (ROND)/Remote Ordnance Neutralization System(RONS)(Initiated 1990)
Explosive Ordnance Disposal

The plan presented several reasons to explain why UGVs are desirable. Firstly, the development and implementation of UGVs reduces the loss of human life and creates operational flexibility on the battlefield and in hazardous, contaminated environments. Secondly, UGVs result in economic savings in manpower and in repetitive operations through the use of unmanned systems as well as reduce and improve training costs and training realism. UGVs can also perform better than humans in many circumstances because they do not feel fear or fatigue, and they can withstand physical stress that the human body simply cannot endure. Lastly, UGVs can serve as a force multiplier that can bring a capability that does not exist among a human-only force (DOD, 1991).

In 1991, the DOD recognized the potential opportunities for these systems in the following areas: reconnaissance, target engagement, logistics, runway repair, minefield detection and neutralization, explosive ordnance disposal, physical security, and nuclear, biological, and chemical operations on the battlefield (DOD, 1991). DOD leadership also saw the value of unmanned systems and the benefit of empowering Soldiers with technology that could make them more lethal without having to place them in dangerous engagements with the enemy.

While clear desire to implement this technology existed, challenges made full implementation difficult. Software development, for instance, was a major challenge for future unmanned systems, and the Office of the Secretary of Defense (OSD) openly acknowledges in the UGVMP that teleoperation was feasible in 1991, but autonomous operation was not. Autonomous operation can save forces money on repetitive operations and reduce manpower costs, but without autonomy, there is actually a manpower burden from unmanned systems.

The 1991 UGVMP states that the program acquisition strategy is based on the coordinated evolution of demonstrated capabilities and user requirements. In the near-term, the focus was placed on teleoperated and teleassisted UGVs. The mid-term focus was on supervised robotics for navigation, recon, surveillance, and target acquisition. The far-term strategy focuses on highly autonomous systems that are derived from artificial intelligence through research primarily conducted by DARPA (DOD, 1991).

In this master plan, there are three projects pursued under the heading 6.3B, which is advanced system development (ASD). The three projects are tactical unmanned ground vehicles (TUGV), rapid runway repair (RRR), and the remote ordnance neutralization device (ROND). Figure 4 gives some perspective on the meaning of 6.3B development funding in relation to the DOD acquisition milestone chart. Table 2 depicts a five-year funding plan for the three projects. The tactical unmanned ground vehicle (TUGV) is the largest program financially and is the main effort of the 1991 UGVMP.

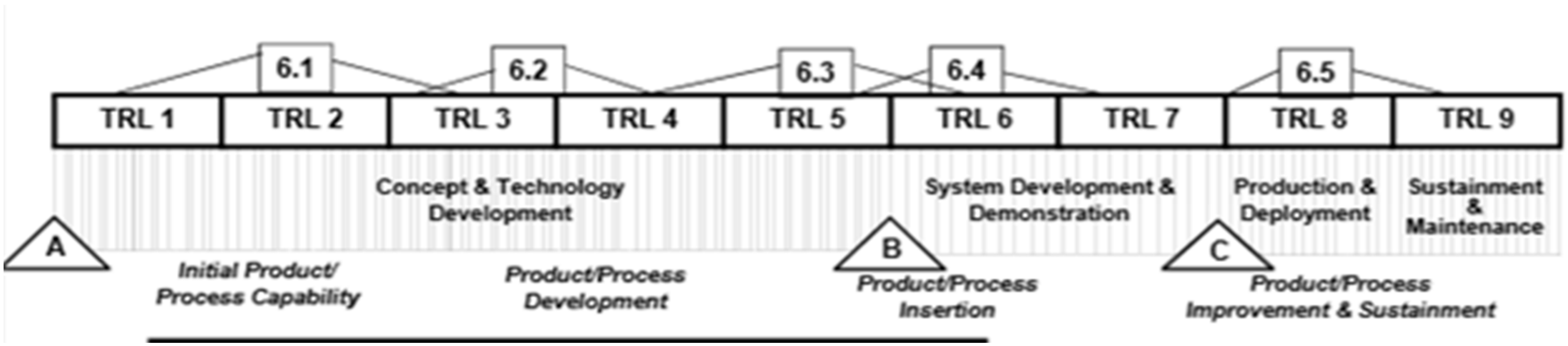


Figure 4. 6.3B Funding in Relation to DOD Acquisition Milestones (from Defense Manufacturing Management Guide for Program Managers, 2012)

Table 2. Planned Funding for 6.3B Development Programs ($M; from DOD, 1991)

	FY90	FY91	FY92	FY93	FY94	Total
TUGV	6.70	7.65	8.10	8.10	3.00	33.90
RRR	0.75	2.00	2.00	1.50	0.50	7.75
ROND	0.80	0.70	1.70	1.60	1.50	7.60

* In addition to the amounts shown, the Air Force has budgeted $0.25 million in FY1990, $0.375 million in FY1991, $0.325 million in FY1992, $0.30 million in FY1994.

a. Tactical Unmanned Ground Vehicle

The first project is a tactical unmanned ground vehicle (TUGV) and the system in development is the surrogate teleoperated vehicle (STV) shown in Figure 5. The TUGV can serve as an operator, which can remotely conduct reconnaissance, surveillance, and target acquisition (RSTA), and nuclear, biological, and chemical (NBC) detection and laser designation. In this document, the project is in the design and build phase with Milestone III projected for 1997, when production of the system is expected to occur. The planned TUGV program schedule is shown in Figure 6.

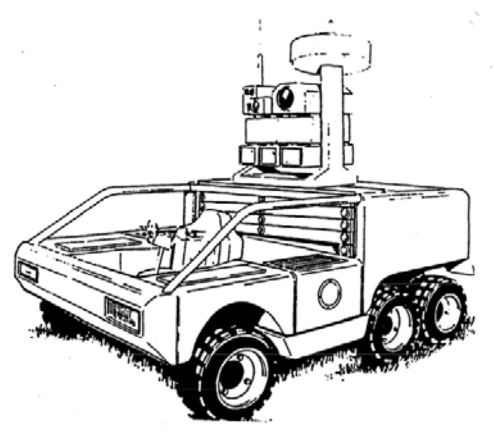


Figure 5. Picture of the Tactical Unmanned Ground Vehicle Program Surrogate Tactical Vehicle (from DOD, 1991)

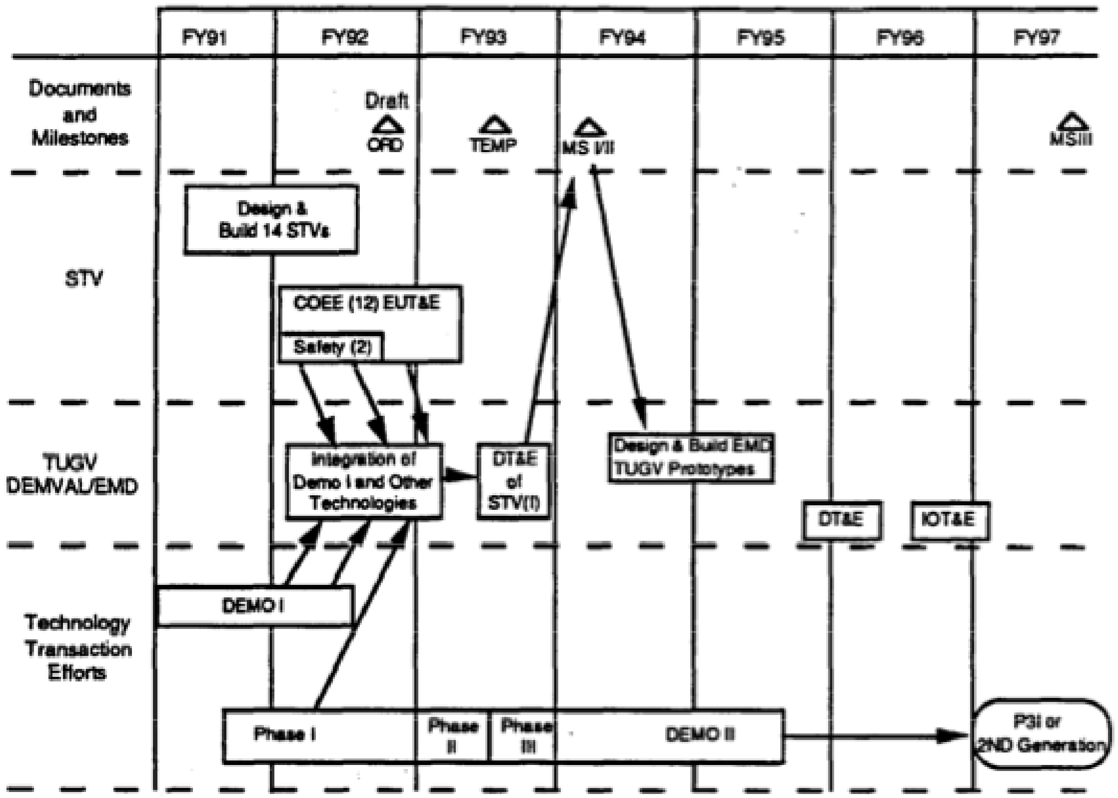


Figure 6. TUGV Program Schedule (from DOD, 1991)

The program schedule shown in Figure 7 displays how funding will transition from OSD to the services that want to acquire the system. Eventually, the OSD is relieved of all financial obligations and the services finance the procurement and sustainment of the system.

		FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97
Schedule	Milestone I/II					1/94			
	DT&E								
	OT&E			COEE EUT&E				IOT&E	
	Milestone III								8/97
Funding ($K)	Required	6700	7650	8100	8100	21600	28400	24500	106600
	OSD	6700	7650	8100	8100	3000			
	Army*					11.9	25.4	22.2	8.0
	USMC*					5.0	5.8	5.1	2.5

* Service amounts show planned funding. The USMC has budgeted $5.0 million in FY1994, $1.4 million in FY1995, $2.0 million in FY1996, and $2.5 million in FY1997

Figure 7. TUGV Program Schedule and Funding (from DOD, 1991)

b. Rapid Runway Repair (RRR)

The second project is the rapid runway repair (RRR), which is a teleassisted repair system that can drive to a damage site, fix holes, and remove debris, thereby enabling the safe removal of personnel from hazardous areas. The RRR system, a semi-autonomous John Deere excavator shown in Figure 8, is used primarily for demonstrating the system's capabilities. The master plan calls for the development of a new excavator vehicle in support of this project. Figure 9 depicts the schedule and funding for the RRR. In 1997, the initiated program should achieve Milestone III, and by 1995, OSD will be phased out of the funding scheme and become the requirement of each service.

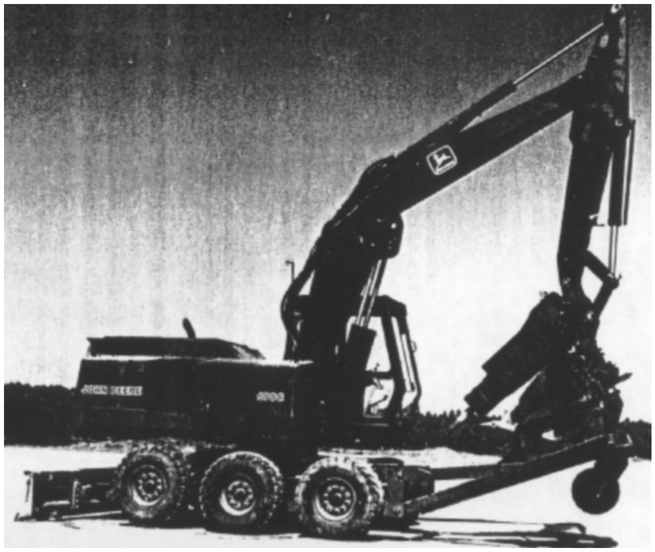


Figure 8. RRR Demonstration Unit (from DOD, 1991)

		FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97
Schedule	Initiation	3/90							
	Milestone II					7/94			
	DT&E			6/92	6/93	10/93–1/94		6/96–7/96	
	OT&E								9/96–2/97
	Milestone III								6/97
Funding ($K)	Required	1000	2375	2325	1800	800	600	3400	2900
	OSD	750	2000	2000	1500	500			
	Service	250	375	325	300	300	600	3400	2900

Figure 9. RRR Program Schedule and Funding (from DOD, 1991)

c. Remote Ordnance Neutralization Device (ROND)

The third project in this master plan is the remote ordnance neutralization device (ROND). This system, depicted in Figure 10, is designed for use by explosive ordnance disposal (EOD) technicians to give them a safe standoff from hazardous explosives. The system consists of a remotely operated platform, a closed circuit TV display, and interchangeable EOD tools that can be used for work purposes by the systems arm. This system is a six-wheeled prototype and looks like the foundation of many EOD systems that are currently in use today such as the TALON or PackBot robots. Like the RRR, this project was also initiated in 1990 and is expected to achieve Milestone III in 1997. As shown in Figure 11, OSD funding expires in 1995, leaving services financially responsible for the project.

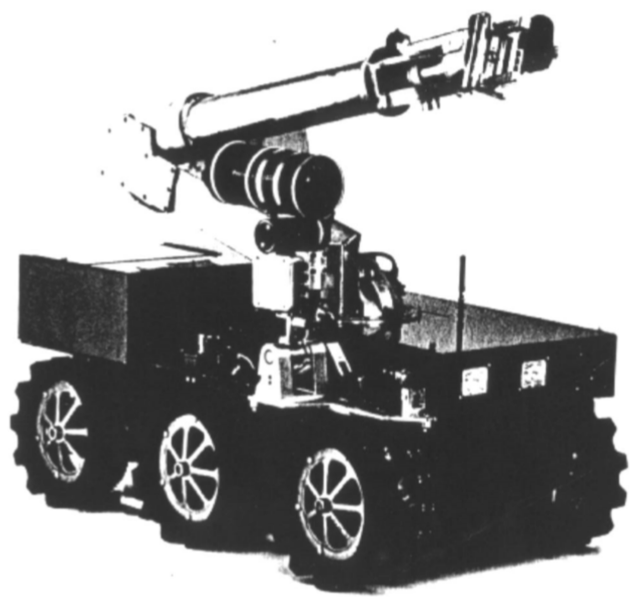


Figure 10. ROND Exploratory Development Prototype (from DOD, 1991)

		FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98
Schedule	Initiation	3/90								
	Milestone II					8/94				
	DT&E				8/93 – 12/93		5/95 – 9/95	5/96 – 1/97 Techeval		
	OT&E								6/97 – 7/97 Opeval	
	Milestone III									4/98
Funding ($K)	Required	800	700	1700	1600	1500	1100	1100	1100	1000
	OSD	800	700	1700	1600	1500	0	0	0	0
	Service						1100	1100	1100	1000

Figure 11. ROND Program Schedule and Funding (from DOD, 1991)

d. DEMOs I and II

The primary purpose of the DEMO I program aims to mature technologies on first-generation UGVs and demonstrate their readiness for acquisition programs (DOD, 1991). In the DEMO I program, five high mobility multi-wheeled vehicles (HMMWVs) were utilized as demonstration vehicles for RSTA and NBC detection operations. DEMO I includes technology from outside the UGV program to maximize technology integration and transfer into the UGV program.

DEMO II strives to mature navigation technologies that allow UGVs to progress from labor-intensive teleoperated systems into supervised autonomous systems (DOD, 1991). DEMO II's primary objective is for the TUGV to be able to conduct RSTA while on the move. The planned funding for DEMO I and DEMO II and the potential for funding of another technology maturation program based on the findings of an ongoing but unnamed study mentioned in this master plan is shown in Table 3.

Table 3. UGVTEE Program Funding ($K; from DOD, 1991)

	FY90	FY91	FY92	FY93	FY94	FY95
Demo I	9700	6080	3300	800		
Demo II		4000	5000	8000	8000	6000
New Initiative					1000	3000
Total	9700	10080	8300	8800	9000	9000

The DEMO I and II program's significance stems from its management by DARPA and includes a large number of key players focused on the R&D of UGVs. The management structure of the program is shown in Figure 12. As a significant collaborative event planned and executed between DARPA, academia, industry, Army R&D, the DOD and other DOD services, the development and advances have impacted the field. The structure of the DEMO II program is shown in Figure 13. DEMOs I and II are key components to the advancement of this emerging technology, and in 1991, the program was still in its infancy. The planned technology exploration is ambitious with the end state of supervised autonomous UGVs as the main objective.

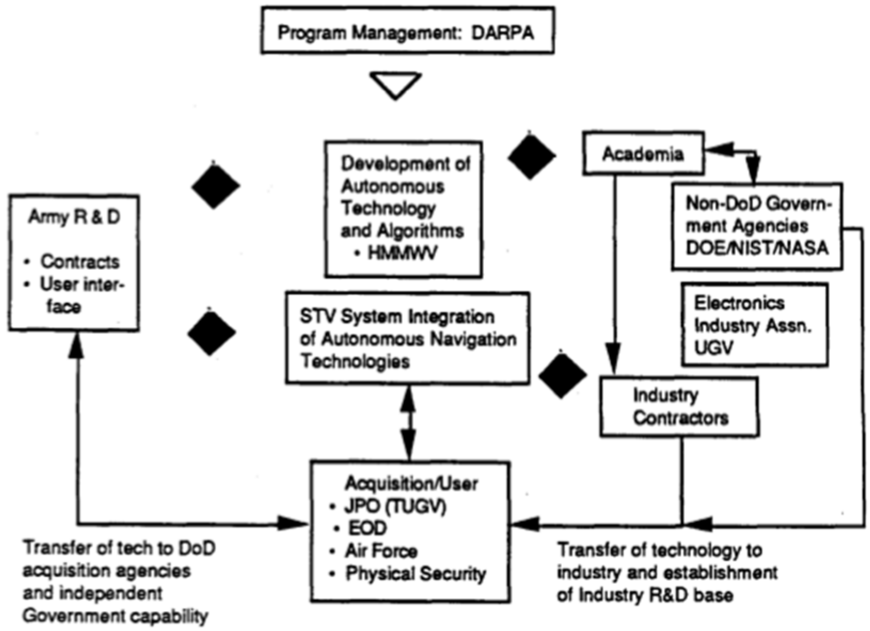


Figure 12. DEMO II Program Interrelationship between Academia, Industry, and Government (from DOD, 1991)

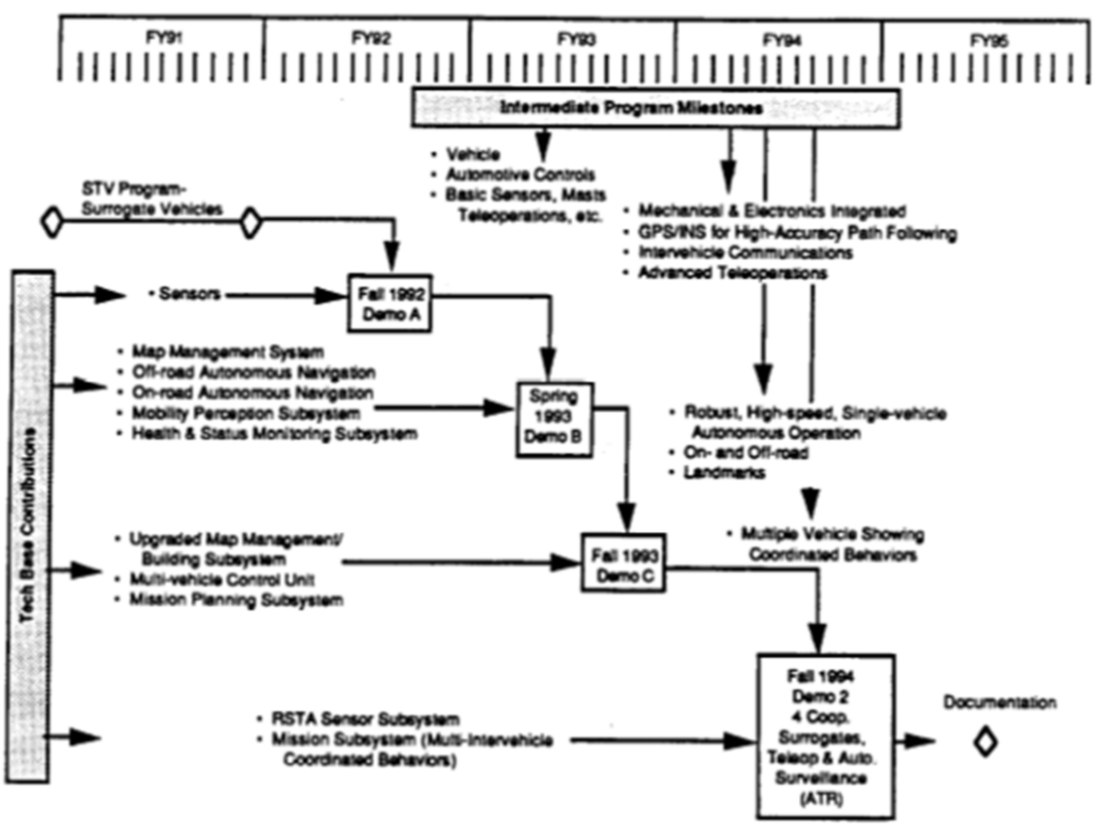


Figure 13. DEMO II Program Milestones (from DOD, 1991)

e. Conclusion

In this document, the RRR and ROND are projects that have a niche—RRR to create runways during full spectrum operations, and ROND within EOD, designed to give operators safe standoff from unexploded ordnance (UXO) during neutralization missions. The TUGV is the premier project; one goal is for TUGV technology to be mature enough to conduct supervised autonomous operations by 2000, and the second goal is for the DOD to mature technology to the point that it is highly autonomous. The plan calls for the fielding of TUGV systems to the Army and Marines by the year 2010. The master plan also discusses the desire for one operator to have the ability to control multiple UGVs overseeing multiple operations through the use of automation.

The master plan concludes with a memorandum of agreement between the tactical warfare program (TWP) and DARPA with specifications "to develop and mature supervised autonomous navigation technologies for advanced system development of unmanned ground vehicles (UGVs) by 1995" (DOD, 1991, p. A-1). By committing to advancing UGVs, DARPA solidifies the commitment to quality, advanced research conducted within the agency, industry and academia, and in turn increases the chances of success of this program and the development of this technology. The funding committed by DARPA and TWP to this program, through DEMO II is shown in Table 4.

Table 4. Funding Agreement between DARPA and TWP ($M; from DOD, 1991)

	FY91	FY92	FY93	FY94	FY95	Totals
TWP	3.0M	5.0M	ROM	8.0M	6.0M	30.0M
DARPA		4.0M	4.0M	4.0M	4.0M	16.0M
Totals	3.0M	9.0M	12.0M	12.0M	10.0M	46.0M

2. 1992 Unmanned Ground Vehicle Master Plan

In the 1991 master plan, the remote control reconnaissance monitor (RECORM) program is no longer a part of the Joint Robotics Program; therefore, there is nothing significant to report. However, in the 1992 master plan, more details about this program emerge, and it becomes evident that the program remains in the engineering, manufacturing & development (EMD) phase, as depicted in Table 5. The RECORM is funded through the joint EOD program with a Milestone III decision planned for 1993 as well as a planned procurement of 340 vehicles with a unit cost of $110,000 per vehicle (DOD, 1992). This program is more mature than other programs mentioned in either document.

Table 5. Requirements Articulation 1992 UGV Master Plan

1992
Requirement
Border Control
Countermine Operations
Explosive Ordnance Disposal
Logistics
Minefield Detection & Neutralization
NBC Detection and Laser Designation
Physical Security
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
Threat/Conflict
Bosnian War (1992-1995)
Somalia (1992-1993)
UGV Solution
Tactical Unmanned Ground Vehicle (TUGV)
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
NBC Detection and Laser Designation
Rapid Runway Repair (RRR)/Robitic Evacuation Vehicle(Rev) (Initiated 1990)
Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas)
Remote Ordnance Neutralization Device (ROND)/Remote Ordnance Neutralization System(RONS)(Initiated 1990)
Explosive Ordnance Disposal
Mobile Detection Assessment Response System - Exterior (MDARS-E) (Initiated 1992)
Reduce manpower by patrolling exterior of buildings and compounds in day, night, hot, cold, wet & dry conditions

Overall Program Schedule

The schedule of programs being tracked in 1992 is shown in Figure 14. The new addition of the RECORM is an update to the schedule from the prior year.

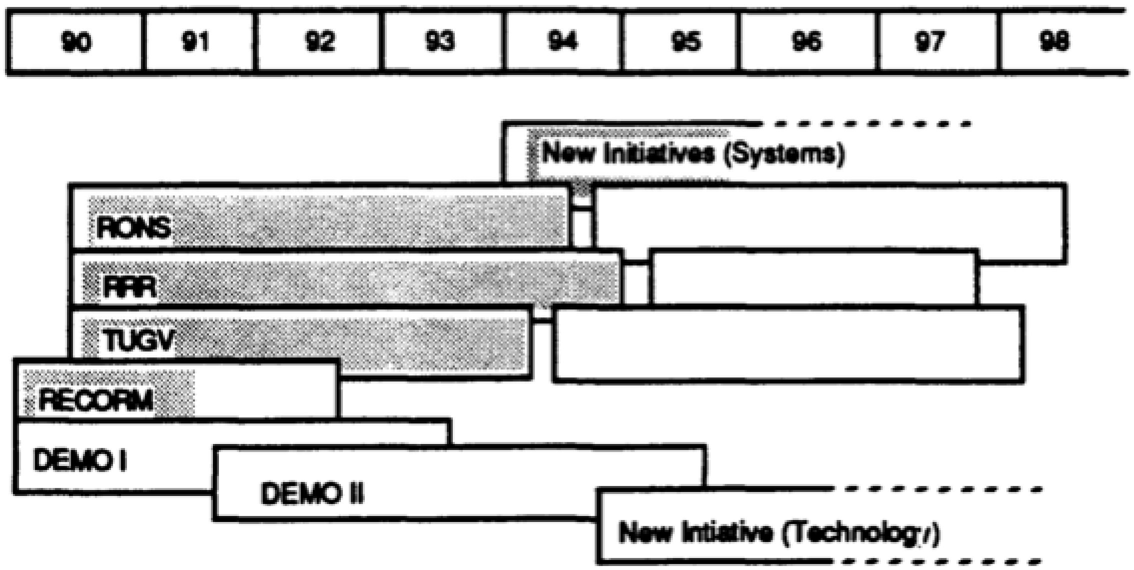


Figure 14. 1992 UGV Program Schedule (from DOD, 1992)

While programs generally remain the same in the latest master plan, there are funding and schedule changes depicted but not directly addressed. The following tables and figures highlight the changes that occurred over the past year.

The change in funding for all programs listed under the 6.3B developmental program's budget, and the top table shown in Table 6 illustrates the prior year's master plan. As shown, the future years funding planned for the TUGV was reduced for 1993 and increased in 1994, ultimately bringing the total program funding down. Subsequently, planned funding for the RRR increased in 1994 along with the program total and the overall funding of the Remote Ordnance Neutralization System (RONS) went down. In 1991, the program, known as ROND, appears to have lost future funding when the name changed, but the difference is not depicted in the table. No reason is given for why the program was changed from ROND to RONS.

Table 6. 1991 Program Funding Compared to 1992 Program Funding ($M, from DOD, 1991, 1992)

1991

	FY90	FY91	FY92	FY93	FY94	Total
TUGV	6.70	7.65	8.10	8.10	3.00	33.90
RRR	0.75	2.00	2.00	1.50	0.50	7.75
ROND	0.80	0.70	1.70	1.60	1.50	7.60

* In addition to the amounts shown, the Air Force has budgeted $0.25 million in FY1990, $0.375 million in FY1991, $0.325 million in FY1992, $0.30 million in FY1994.

1992

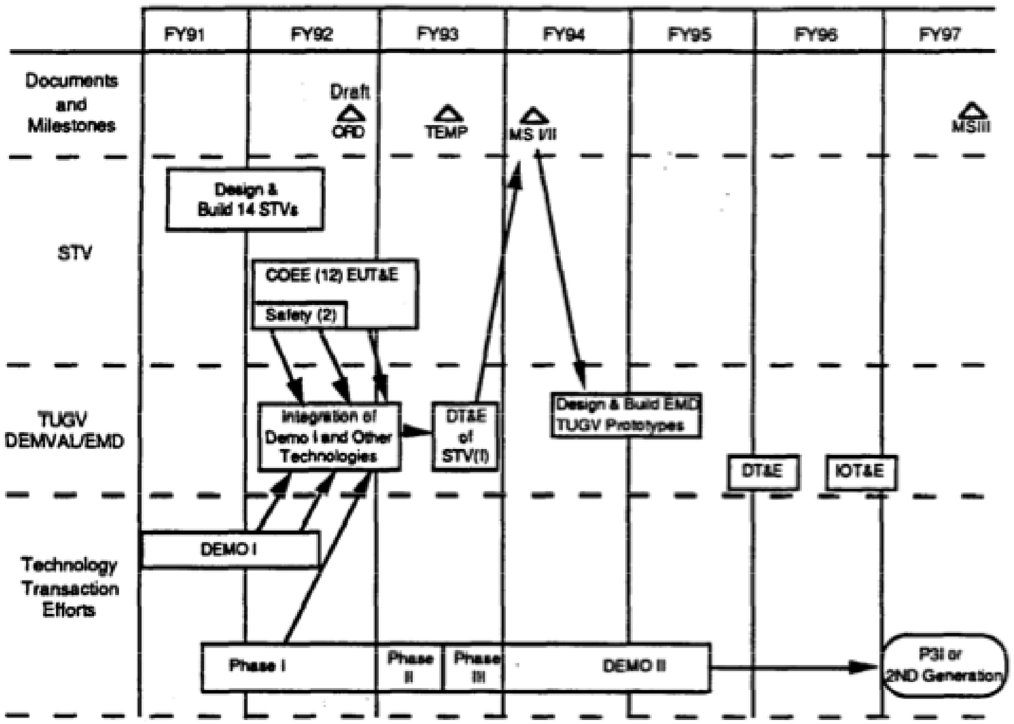
	Prior Years	FY92	FY93	FY94	Total
TUGV	14.35	8.10	7.80	6.00	32.95
RRR[a]	2.75	2.00	1.50	1.00	8.80
RONS[b]	1.50	1.70	1.60	1.50	6.80

[a] In addition to the amounts shown, the Air Force has budgeted $0.25 million in FY 1990, $0.375 million in FY 1991, $0.325 million in FY 1992, and $0.30 million in FY 1993 and FY 1994.

[b] In addition to the amounts shown, the Navy has budgeted $0.40 million in FY 1992 and $0.90 million in FY 1993.

a. TUGV from 1991 to 1992

The slippage of the TUGV schedule from 1991 to 1992 is shown in Figure 15. The Milestone III decision shows a one-year shift from FY97 to FY98, which also shifted the planned second generation TUGV to the same year. The TUGV demonstration, validation, and EMD category resulted in the extension in duration of various events and moved the estimated completion date further into the future. As a result, the design and build of EMD TUGV prototypes completion occurs in the first quarter (QTR) of FY96 instead of the second QTR of FY95 with DT&E, not concluding until the last QTR of FY97 as opposed to the first QTR of FY96. This event also doubled the length of time to complete. Lastly, IOT&E shifts to completion in FY98 instead of the first QTR of FY97. The duration of this event was also extended by almost three months.



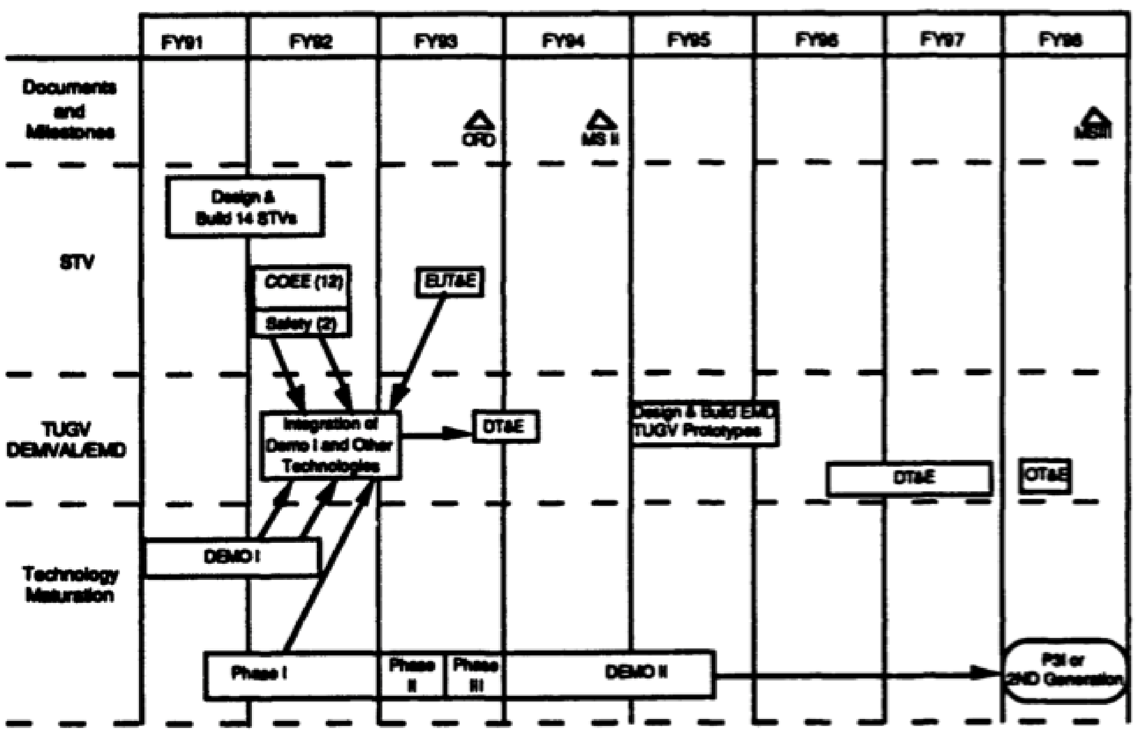


Figure 15. 1991 TUGV Schedule Compared to 1992 TUGV Schedule (from DOD, 1991, 1992)

The TUGV funding changes from the 1991 to 1992 master plans is shown in more detail in Figure 16. The OSD plans to increase funding by 100% in FY94 while the Army drastically reduces its funding of TUGVs from FY94 to FY97. The Marines also reduce funding to the program, but only in FY95 and FY96. However, the plan does not address the required amount planned for the 1991 master plan. There is a significant gap between the amount required and what is planned in 1991.

		FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97
Schedule	Milestone I/II					1/94			
	DT&E								
	OT&E			COEE EUT&E				IOT&E	
	Milestone III								8/97
Funding ($K)	Required	6700	7650	8100	8100	21600	28400	24500	106600
	OSD	6700	7650	8100	8100	3000			
	Army*					11.9	25.4	22.2	8.0
	USMC*					5.0	5.8	5.1	2.5

* Service amounts show planned funding. The USMC has budgeted $5.0 million in FY1994, $1.4 million in FY1995, $2.0 million in FY1996, and $2.5 million in FY1997

		FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97
Schedule	Milestone II								
	DT&E								
	OT&E			COEE	EUT&E				
	Milestone III								
Funding ($K)	OSD	6700	7650	8100	7800	6000			
	Army					6000	6300	6500	6800
	USMC					5000	1400	2000	2500

Figure 16. 1991 TUGV Schedule and Funding Compared to 1992 TUGV Schedule and Funding (from DOD, 1991, 1992)

According to the 1992 master plan, the achievement of Milestone III results in the procurement of 1,200 TUGVs. The goal of the STVs at this point is to provide users with familiarization of this system, refine requirements, and determine further operational capabilities and benefits before entering into EMD in FY94 (DOD, 1992). The document states that 14 STVs were ordered in 1990 and have been delivered, two of which are designated for safety and technical performance tests, and 12 for operational testing.

b. RRR from 1991 to 1992

From 1991 to 1992, very little changed in regard to the RRR schedule and funding. On the other hand, OSD funding for FY94 increased from $500,000 to $1 million, with no other changes reported.

The 1992 master plan stated that an EMD decision for the RRR is set for FY94 with the Milestone III decision expected to occur in FY97. The plan called for the procurement of approximately 125 RRRs. In 1991, Eagle-Picher industries was awarded the contract for design, development, and fabrication of the RRR prototype.

c. ROND/RONS from 1991 to 1992

Figure 17 is a picture of the RONS; Figure 18 depicts a comparison of the 1991 ROND program against the 1992 RONS program. ROND became RONS in the 1992 master plan, but there was not much change to the funding or schedule as a result of the name change. In 1992, there was a planned increase in service funding in FY92 and FY93.

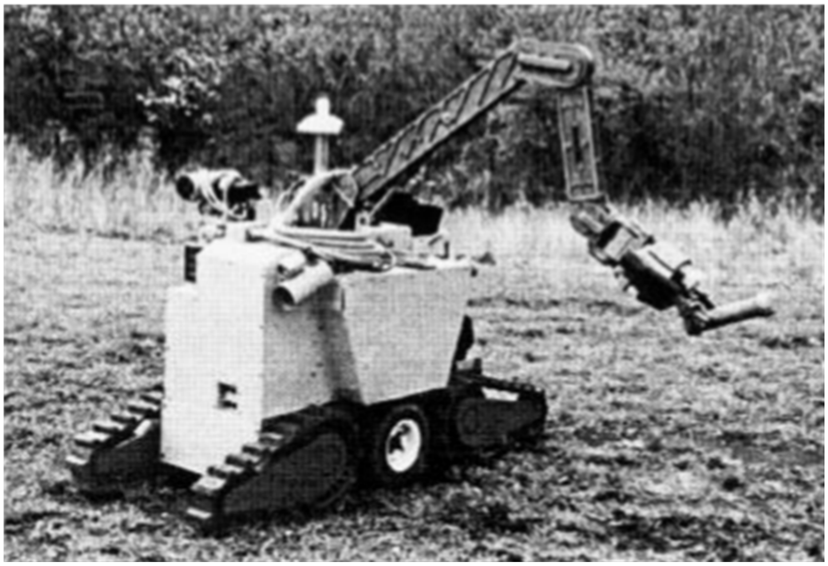


Figure 17. RONS Exploratory Developmental Prototype (from DOD, 1991)

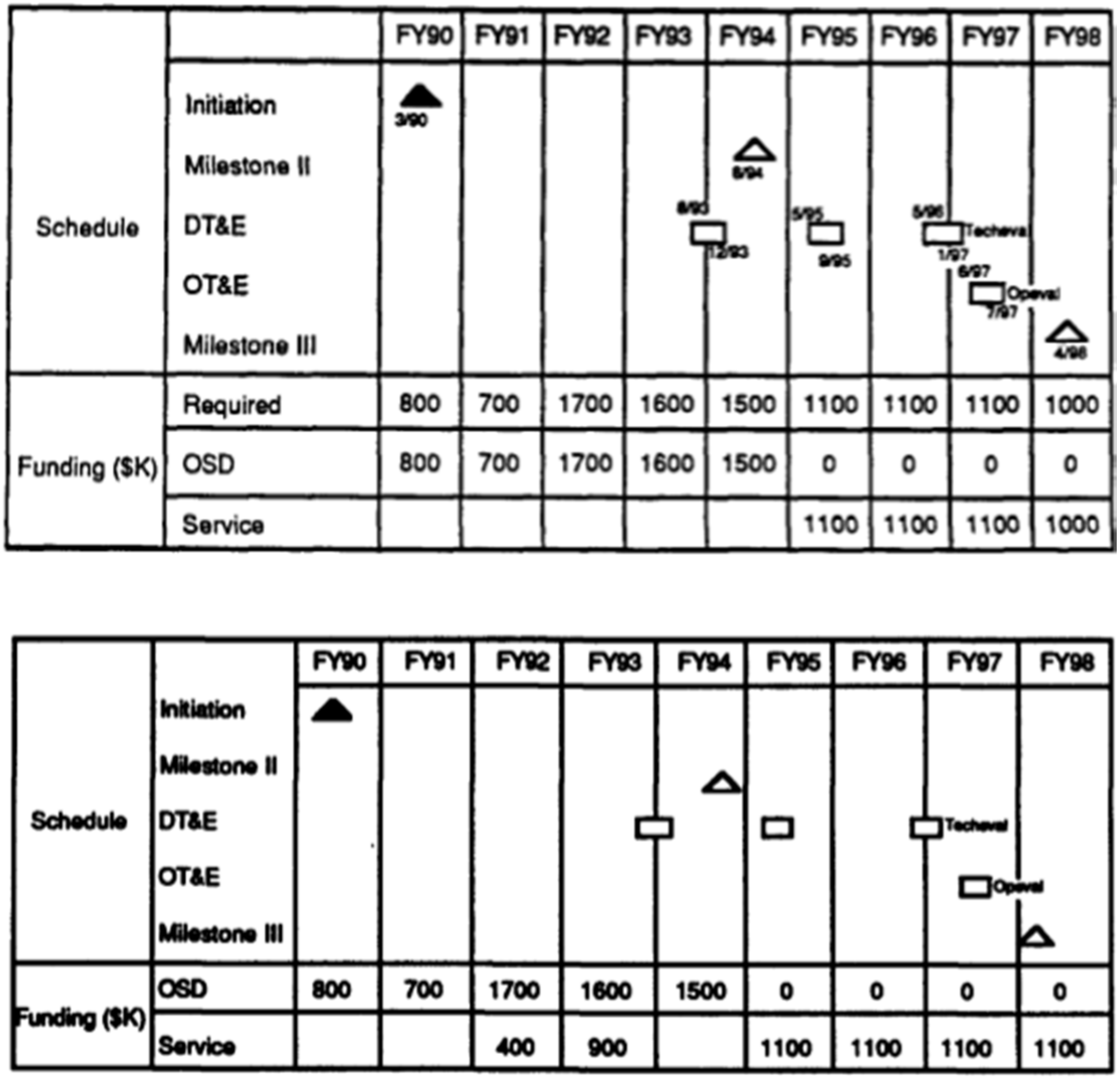


Figure 18. 1991 RONS Schedule and Funding Compared to 1992 ROND Schedule and Funding (from DOD, 1991, 1992)

EMD for RONS, designed primarily for use in the EOD community, was planned for FY94, and the 1992 master plan called for the procurement of over 200 RONS beginning in FY98. In 1991, a contract to design, develop, and fabricate an advanced development model (ADM) was awarded to Battelle, Pacific Northwest Laboratories (DOD, 1992). Before RONS can achieve Milestone II, it must complete a long list of apparent challenging tasks in relation to the time period and level of technology maturation. The tasks include the following: the ability to be used continuously for six hours, to have one hour of battery life without engine use, to climb 450 stairs, to travel across grass, to be able to lift 100 pounds, to operate with 1000 meter separation between the unit and operator, and to provide EOD technicians with manipulator functions.

d. DEMOs I and II from 1991 to 1992

According to the 1992 master plan, DEMO I was almost complete and achieved its primary objective of maturing existing technology and demonstrating critical system component technologies for first generation UGVs. DEMO I accomplished a few key autonomous navigation feats: road following, path retrace, and path retro traverse with automated turnaround and backup (DOD, 1992). Obstacle detection and avoidance during autonomous operations is still a limiting factor; at this time, the vehicles can avoid collisions with large objects, but are not sophisticated enough to function in traffic or in many varieties of terrain and man-made environments.

During this time, path retrace is seen as one of the key breakthroughs for TUGVs; it allows the operator to command the UGV to return home and provides the ability to supervise or conduct other operations. This is also considered a key integration into the RONS program to further reduce EOD technician's exposure to hazards while trying to recover equipment at the conclusion of a mission.

In the 1992 master plan, DEMO II is only in Phase 1 with emphasis mainly on HMMWVs. Figure 19 presents the DEMO II program in its four phases to its planned completion in FY95.

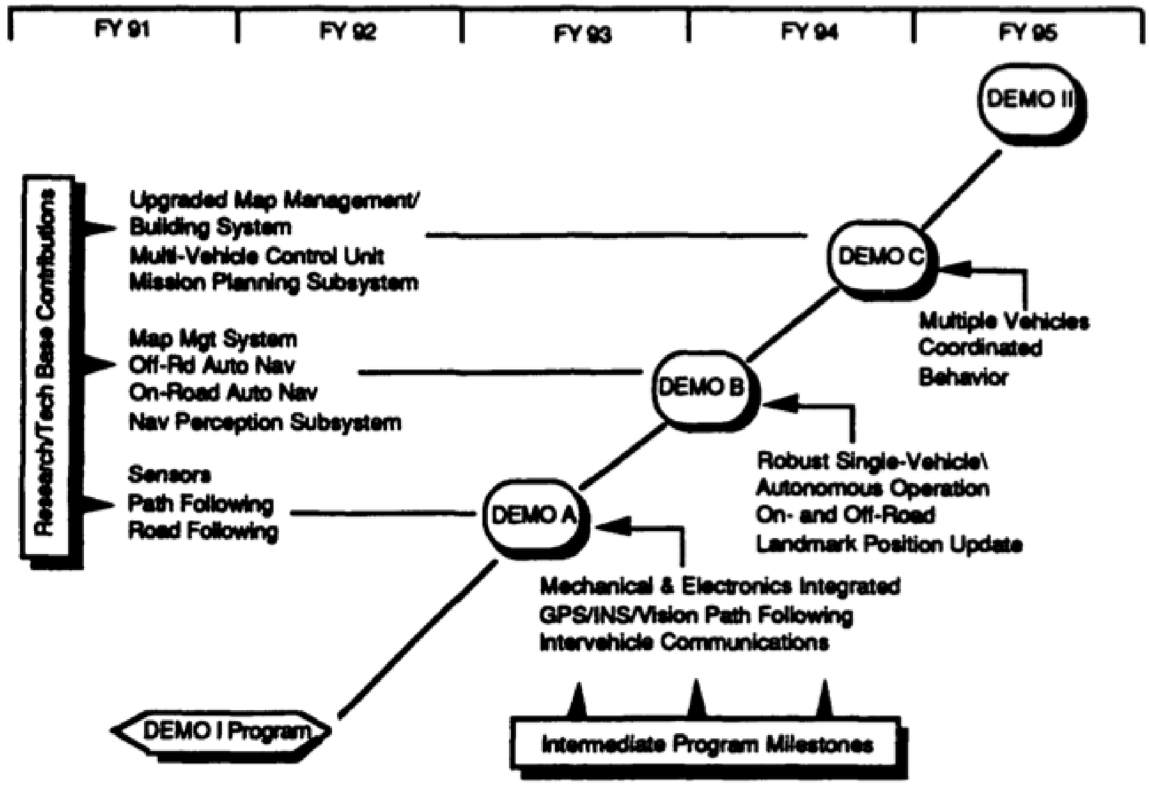


Figure 19. DEMO II Program Overview (from DOD, 1992)

e. Conclusion

The master plan presents new potential systems and uses that may come to fruition in the near future. Also, for the first time, the mobile detection assessment response system—exterior (MDARS-E) is mentioned with a goal of significantly reducing manpower by patrolling the exterior of buildings and compounds in day, night, hot, cold, wet, and dry conditions.

Environmental restoration is another projected use for UGVs which could meet a large requirement in the coming years. Other recommended uses for UGVs at this time include countermine operations, logistics, and border control (DOD, 1992). As the systems continue to evolve and successfully demonstrate their capabilities, the identification of more uses could occur in an effort to reduce the burden on manpower and to further eliminate unnecessary risk among the force.

3. 1993 Unmanned Ground Vehicle Master Plan

The overall master plan for this year maintains the same purpose as the previous plans, but there are a few changes that come to the forefront early in the document. This UGVMP bluntly states that the tactical unmanned ground vehicle (TUGV) program, as it relates to supporting the infantry, is the primary focus of the whole UGV program. The document further explains that the TUGV is part of a system development strategy that focuses on the integration of UGVs with other land combat systems and forces on the battlefield. The second focus of the UGV program at this point is to support more niche and narrow requirements such as EOD, where automating human functions is desired. The engineer vehicle teleoperation capability (EVTC) is a new program in the 1993 master plan and is covered in greater detail later in this section. The requirements that led to the solution for that year is shown in Table 7.

Table 7. Requirements Articulation 1993 UGV Master Plan

1993
Requirement
Border Control
Breaching
Countermine Operations
Environmental Cleanup
Explosive Ordnance Disposal
Logistics
Minefield Detection & Neutralization
NBC Detection and Laser Designation
Physical Security
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
Remote Mine Clearance
TUGV - Supporting the Infantry
UXO Emerged
Threat/Conflict
Bosnian War (1992-1995)
Somalia (1992-1993)
UGV Solution
Tactical Unmanned Ground Vehicle (TUGV)
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
NBC Detection and Laser Designation
Rapid Runway Repair (RRR)/Robitic Evacuation Vehicle(Rev) (Initiated 1990)
Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas)
Remote Ordnance Neutralization Device (ROND)/Remote Ordnance Neutralization System(RONS)(Initiated 1990)
Explosive Ordnance Disposal
Mobile Detection Assessment Response System - Exterior (MDARS-E) (Initiated 1992)
Reduce manpower by patrolling exterior of buildings and compounds in day, night, hot, cold, wet & dry conditions
Engineer Vehicle Teleoperation Capability (EVTC) (Initiated 1993)
Remote Mine Clearance
Breaching
Environmental Cleanup
**This year UGVs are categorized by size:*
Small - TUGV, RONS, MDARS-E
Medium - EVTC
Large - REV
*** Funding for RRR dissipated due to collapse of the Soviet Union - RRR no longer required/Program Renamed REV*
****Shift focus from cold-war oriented plan to Desert Shield/Desert Storm*
Reduction in Budget for TUGV

As mentioned in the 1992 UGVMP, the remote control reconnaissance monitor (RECORM) program is managed by the joint services EOD office, and this program is no longer visible in the 1993 UGVMP. One statement indicates that the RECORM completed development, but making an assessment of its status proves difficult.

The 1993 UGVMP is also the first sign of categorizing the UGVs by size. The TUGV, remote ordnance neutralization system (RONS), and mobile detection assessment response system-exterior (MDARS-E) are considered small UGVS. Potential armor and artillery UGVs are categorized as medium and the EVTC and robotic excavation vehicle (REV) are categorized as large UGVs.

The 1993 UGVMP schedule for all UGV programs and the technology development programs that support maturation of component technologies is shown in Figure 20. This figure indicates the status (approved, draft, or potential) of each program. All "potential" category programs are without a schedule, with the exception of the REV. Since it is a spinoff of the rapid runway repair (RRR) and much of the previous program infrastructure was left in place, technology was transferred to the new requirement.

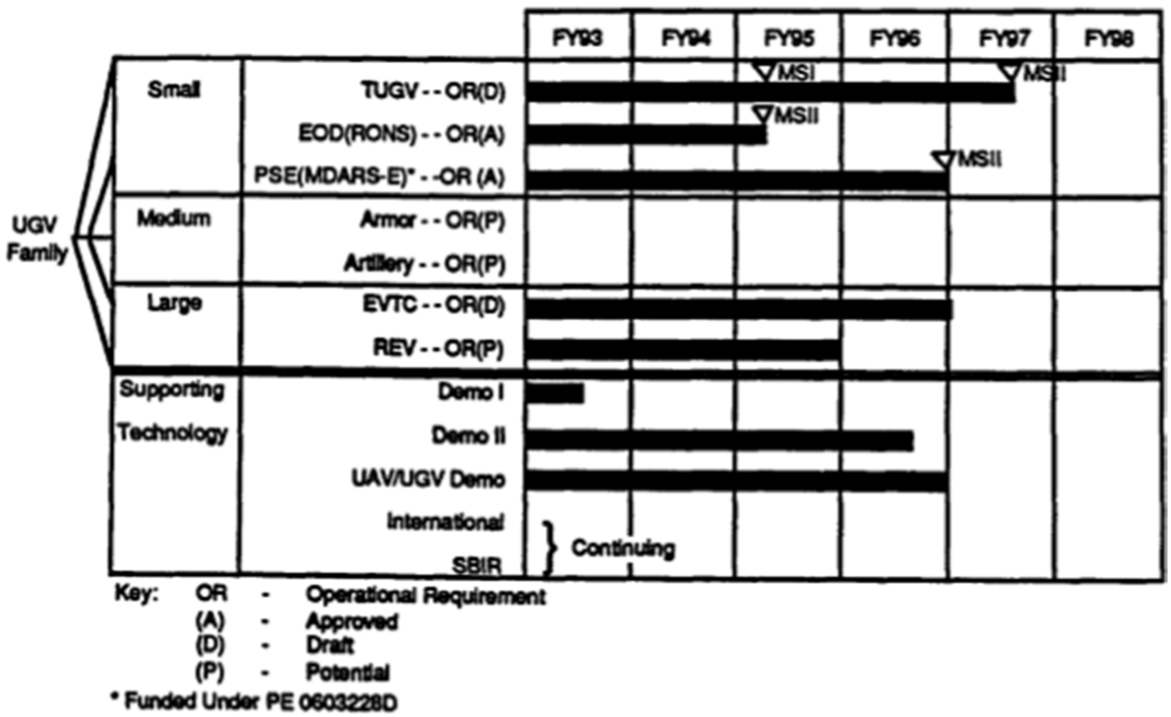


Figure 20. 1993 UGV Program Schedule (from DOD, 1993)

The planned funding changes for the TUGV, RRR/REV, and RONS is shown in Figure 20. In the 1992 version of this table, only three future years were projected; now four are present in the 1993 version. By analyzing program funding, it becomes apparent that the TUGV is the primary focus of the UGV program as it receives the most funding; however, this does include the EVTC program funding as well. More money is also allocated to each future year than was planned in 1992 with all other program funding on the table remaining unchanged.

Table 8. 1993 Planned Funding for 6.3B Development Programs ($M; from DOD, 1993)

	Prior Years	FY93	FY94	FY95	FY96	Total
TUGV/EVTC	22.80	8.70	10.00	11.00	10.50	61.95
REV/RRR[a]	4.75	1.50	1.10	1.40	1.30	10.05
RONS[b]	3.20	1.60	1.50	.40	0	6.70

[a] In addition to the amounts shown, the Air Force has budgeted $0.25 million in FY 1990, $0.375 million in FY 1991, $0.325 million in FY 1992, and $0.30 million in FY 1993 and FY 1994.

[b] In addition to the amounts shown, the Navy has budgeted $0.40 million in FY 1992 and $0.90 million in FY 1993.

a. TUGV from 1992 to 1993

The 1993 UGVMP states that the TUGV effort has expanded to include the sustainment of the UGVs developed over the past few years being utilized for testing (DOD, 1993). At this time, both the TUGV program and the MDARS-E program are working together to promote commonality between the two systems and to share technology development. It is worthwhile to mention that the MDARS-E does not receive support by the joint robotics program (JRP).

In 1992, the only TUGV system mentioned was the surrogate teleoperated vehicle (STV) displayed in Figure 21. In this master plan, there are five other TUGV systems. The Teleoperated mobile all-purpose platform is shown in Figure 22, the teleoperated vehicle is shown in Figure 23, the surveillance and assessment robot for GI enhancement is shown in Figure 24, the Gecko is shown in Figure 25, and the teleoperated high mobility multi-wheeled vehicle is shown in Figure 26.

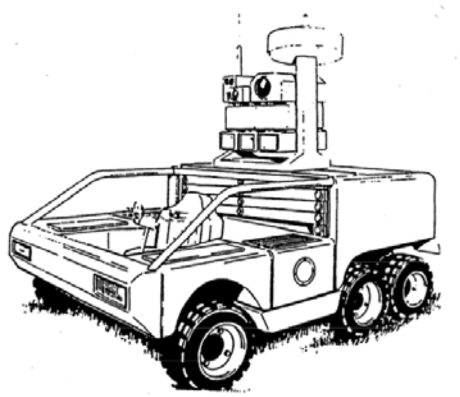


Figure 21. Surrogate Teleoperated Vehicle (STV) (from DOD, 1992)

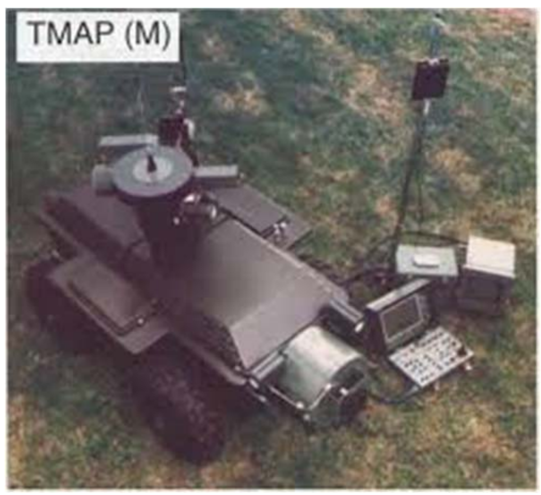


Figure 22. Teleoperated Mobile All-Purpose Platform (TMAP) (from DOD, 1992)

Figure 23. Teleoperated Vehicle (TOV) (from DOD, 1992)

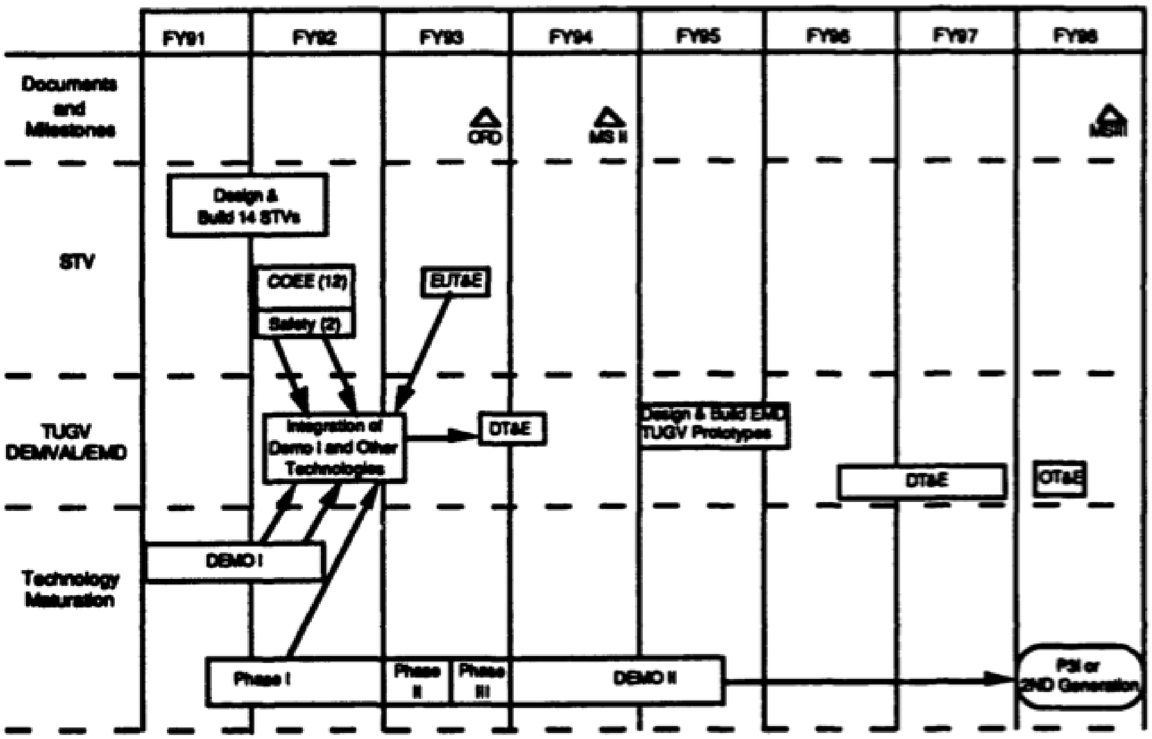
Figure 24. Surveillance and Assessment Robot for GI Enhancement (SARGE) (from DOD, 1992)

Figure 25. Gecko (from DOD, 1992)

Figure 26. Teleoperated High Mobility Multi-wheeled Vehicles (HMMWVs) (from DOD, 1992)

The 1992 TUGV program plan compared to the 1993 TUGV program plan is shown in Figure 27. In the 1992 UGVMP, Milestone II was planned for FY94 and Milestone III was projected toward the end of FY98. In 1993, Milestone II had shifted about three years to the right and Milestone III was no longer on the schedule, which projected out to FY98. The master plan also stated that EMD was planned to begin in FY97 and conclude in FY01. In the 1992 master plan, EMD was scheduled to being in FY95 and conclude in FY96. The schedule slippage is significant within this program.

In 1992, 1,200 TUGVs were expected to be procured, but in the 1993 master plan, this number was reduced to 1,100 total procured TUGVs.



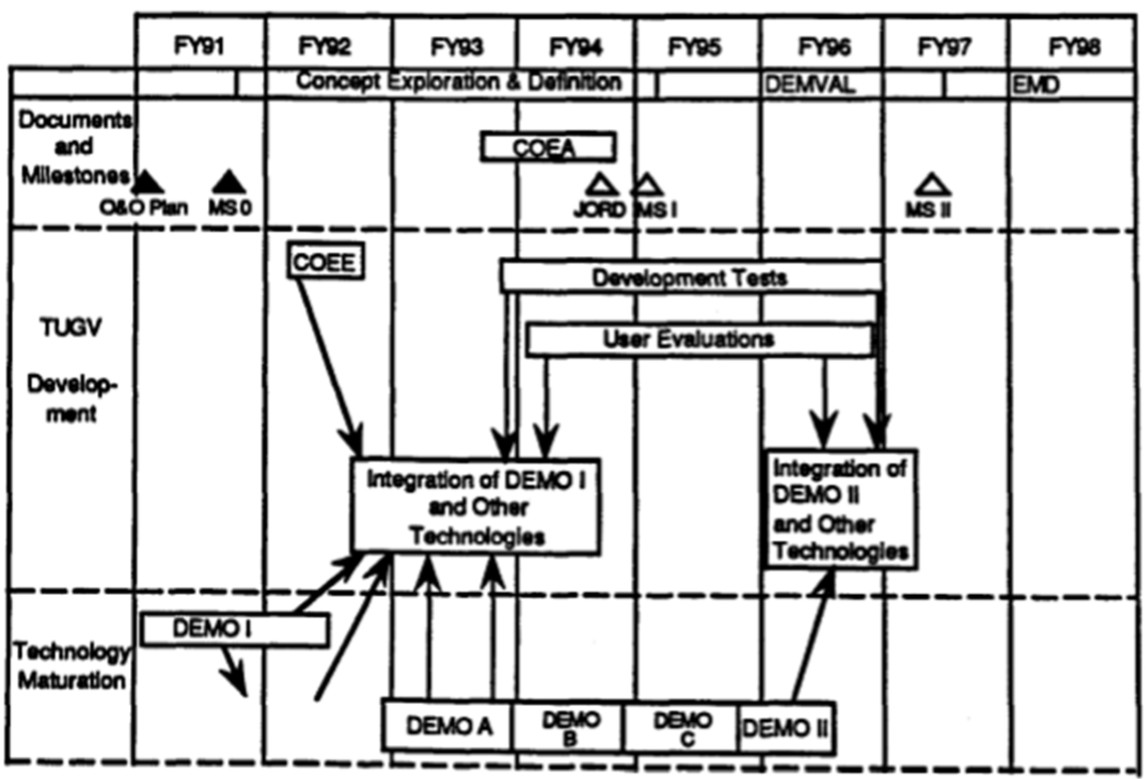


Figure 27. 1992 TUGV Schedule Compared to 1993 TUGV Schedule (from DOD, 1992, 1993)

From 1992 to 1993, the TUGV program schedule and funding displayed in Figure 28 has also evolved, and the individual services' funding obligation is no longer visible. In the 1992 master plan, OSD TUGV funding was only $6 million in FY94, and this was supposed to be the last year of OSD funding support to the TUGV program. From that point forward, it would be the services' responsibility because the program was planned to be in the EMD phase by this point. In the 1993 master plan, the OSD funding was raised to $10 million in FY94 and OSD funding of the TUGV program was extended to FY97, which is the new planned date for EMD with service funding towards the program expected to resume during the EMD phase.

		FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97
Schedule	Milestone II					△			
	DT&E								
	OT&E			COEE	EUT&E				
	Milestone III								
Funding ($K)	OSD	6700	7650	8100	7800	6000			
	Army					6000	6300	6500	6800
	USMC					5000	1400	2000	2500

		Prior Years	FY92	FY93	FY94	FY95	FY96	FY97
Schedule	Milestones					△ MS I		△ MS II
	Dev. Test							
	User Eval.		COEE					
Funding	OSD	14,350	8100	7800	10,000	11,000	10,500	8,000

Figure 28. 1992 TUGV Funding and Schedule Compared to 1993 TUGV Funding and Schedule (from DOD, 1992, 1993)

b. RONS from 1992 to 1993

With RONS moved into the small UGV category in 1993, it makes more sense to arrange the presentation in order by category. The changes to the RONS schedule and program from 1992 to 1993 is shown in Figure 29. In the 1993 master plan, OSD funding for this program extended an additional year to FY95 and the services funding for FY93 increased from $400,000 to $1.7 million. From a schedule standpoint, DT&E, OT&E and Milestone III all shifted further to the right, by at least six months for all three categories mentioned previously.

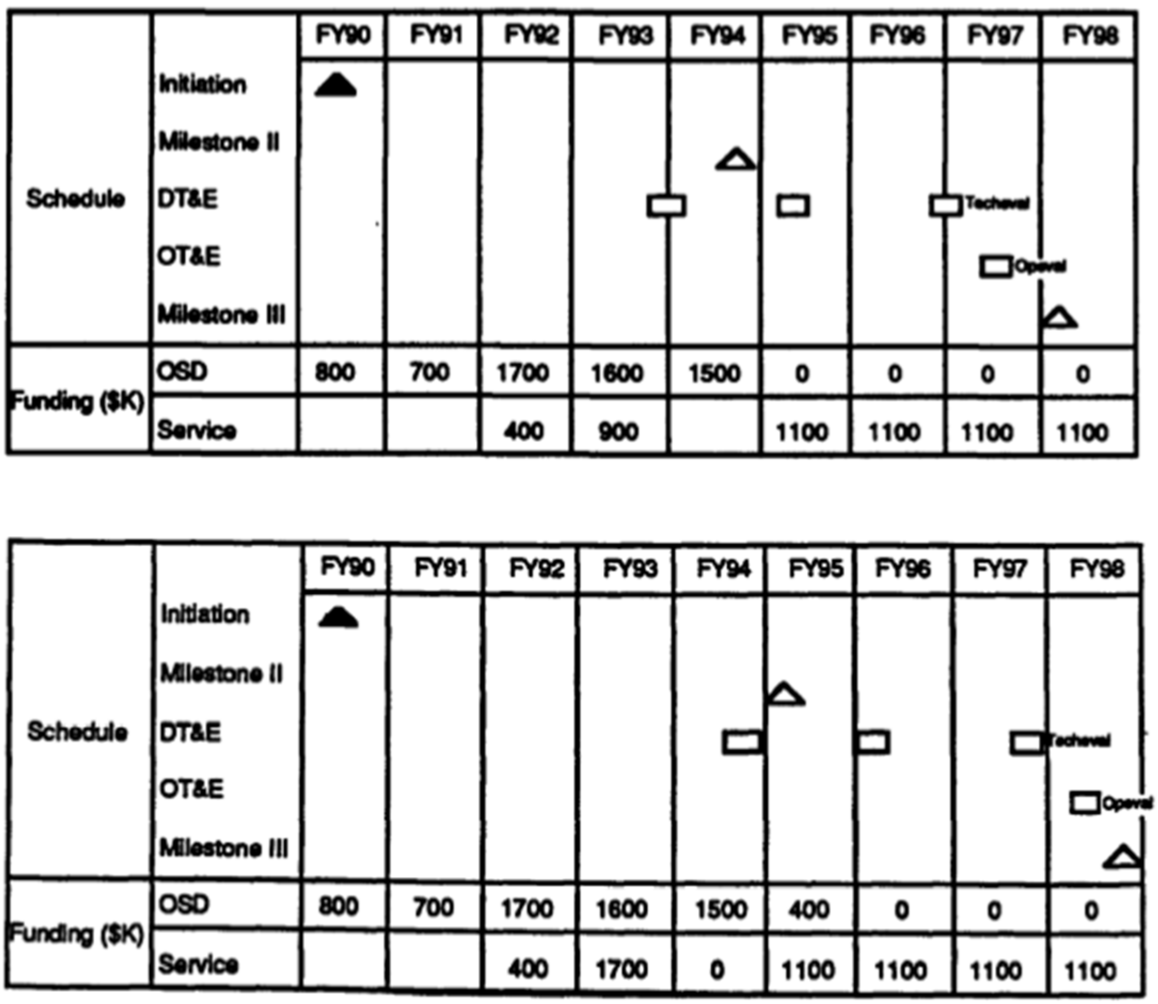


Figure 29. 1992 RONS Funding and Schedule Compared to 1993 RONS Schedule and Funding (from DOD, 1992, 1993)

c. RRR/REV from 1992 to 1993

From 1992 to 1993, the RRR program changed to the robotic excavation vehicle (REV), but the collapse of the Soviet Union called for the RRR dissipation and the withdrawal of program funding. However, requirements for equipment to clear countryside and ranges of unexploded ordnance (UXO) emerged at this time. As a result, the technology developed under the RRR program in the DEMO I and II programs were transferred to the REV to meet this requirement.

The picture shown in Figure 30 is the REV in 1993 and picture shown in Figure 31 compares the 1992 RRR schedule to the 1993 REV schedule. The RRR program was converted into the REV program during this period, as the requirements changed based on the collapse of the Soviet Union. Much of the RRR data remained on the improved REV schedule, but overall, the program funding generally increased and the schedule slipped to the right. In 1992, the OSD funding of the RRR program was expected to terminate in FY94; instead, the FY94 increased funding by $100,000 and extended out to FY97 when Milestone II was projected. From FY93 to FY98, service funding increased in all years except FY96, where the funding decreased, and FY97 where the funding stays the same.

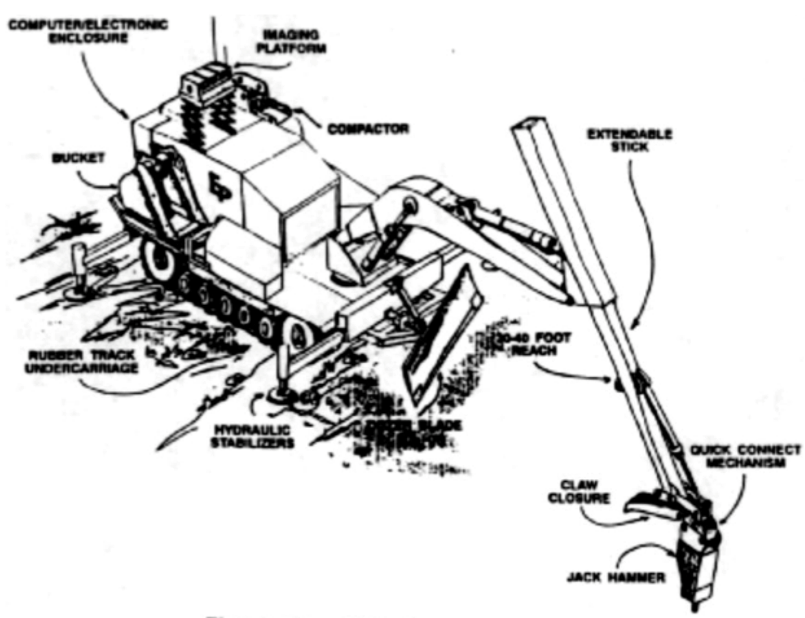


Figure 30. REV Conceptual Design (from DOD, 1993)

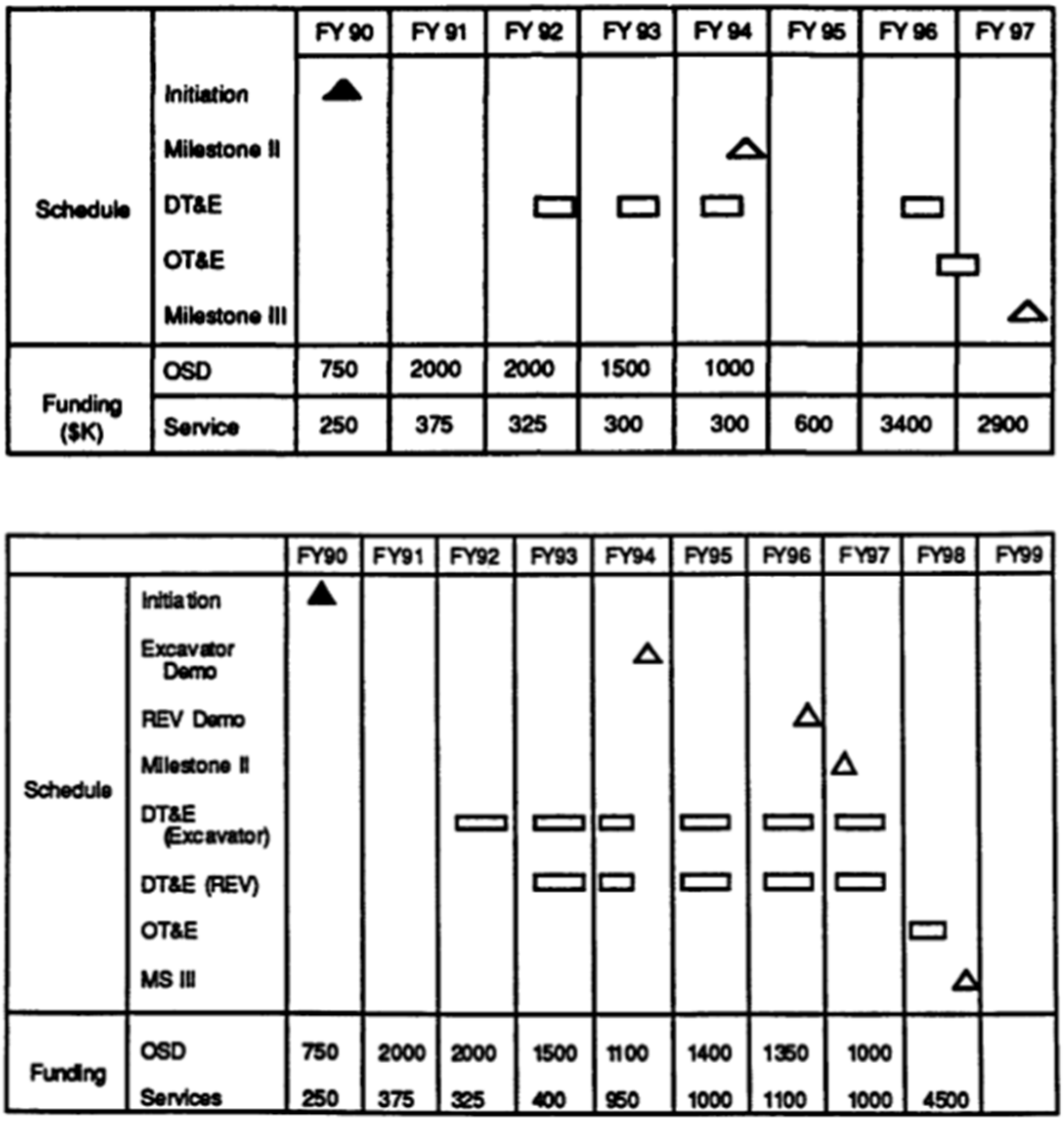


Figure 31. 1992 RRR Funding and Schedule Compared to 1993 REV Funding and Schedule (from DOD, 1992, 1993)

d. EVTC 1993

The engineer vehicle teleoperation capability (EVTC) was a new program in the 1993 master plan. It is basically a generic modular kit that can be installed on a variety of existing manned vehicles, allowing an operator to remotely control the vehicle from a distance, or from another vehicle (DOD, 1993). This kit can be overridden manually by an operator and it can be used for remote mine clearance, breaching, environmental cleanup, and for many other undetermined and unimagined uses.

There are requirements for this program on M1 and M60 tanks. The schedule is very raw and shows program initiation in FY93 and a time line with no milestones that extends through FY96. This is an operational requirement (OR) in the draft (D) stage so more information is expected in future editions if the program is more formally implemented.

e. DEMOs I and II from 1992 to 1993

DEMO I was concluded in April 1992. The change to the DEMO II program from 1992 to 1993 is shown in Figure 32. In the 1993 UGVMP, all intermediate milestones for DEMO II shifted one year into the future, and the overall program was planned to conclude in FY96 as opposed to FY95.

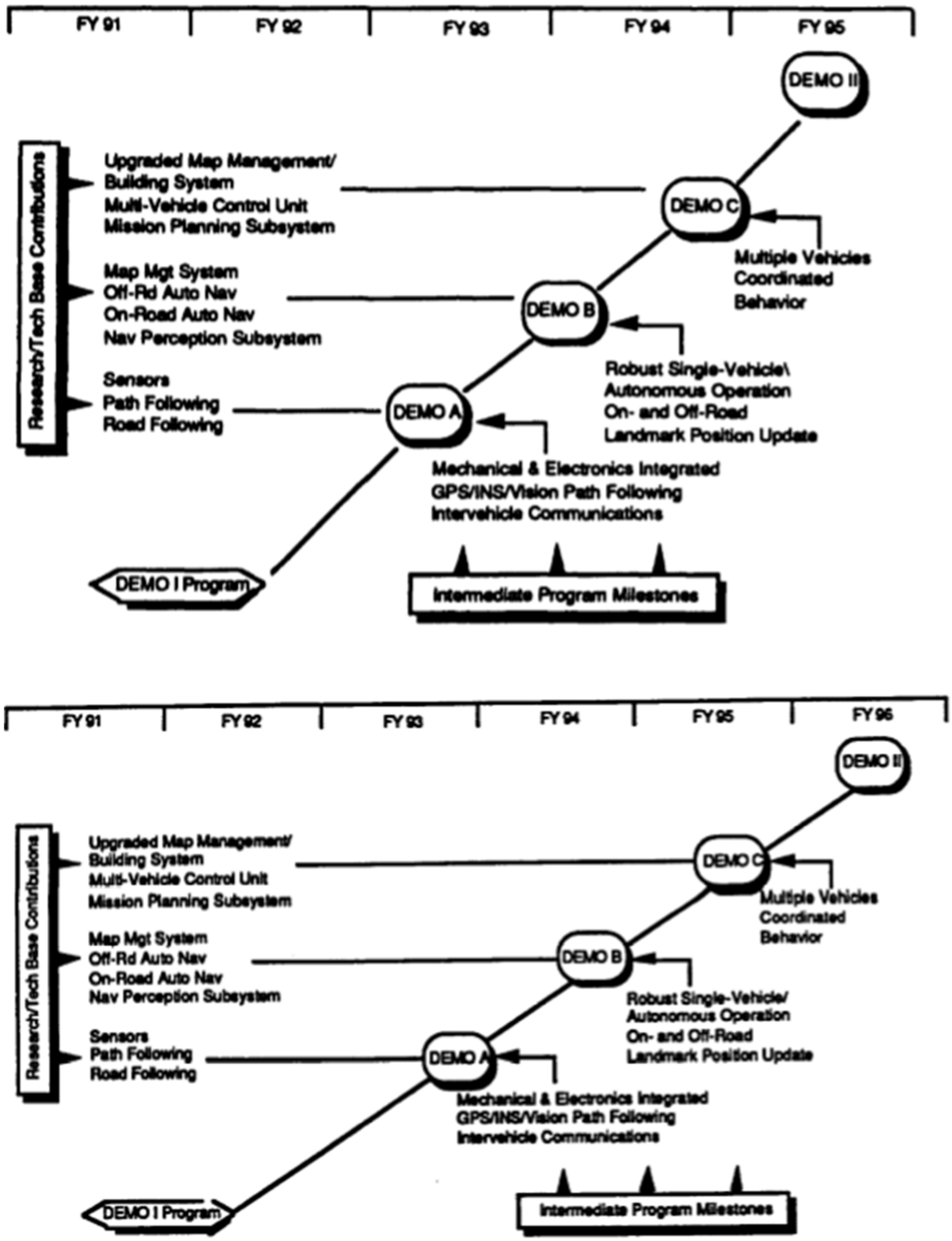


Figure 32. 1992 DEMO II Program Schedule Compared to 1993 DEMO II Program Schedule (from DOD, 1992, 1993)

Despite the ongoing research in autonomous navigation, cross-country navigation remains elusive with an unfulfilled capability gap.

f. Conclusion

For the most part, there are significant changes to the funding of the UGV program. Schedules for each UGV program have shifted to the right; possibly as a result of poor program management, but more likely as a result of budget uncertainty, or the changing strategic landscape caused by the collapse of the Soviet Union. The document does state that the 1992 UGVMP was a cold-war oriented plan and more consideration for this technology must be placed on lessons learned from Desert Shield and Desert Storm. This change in strategy may also have been the catalyst that caused the drastic changes to each of the programs covered.

The master plan stated that the reduction in future DOD budgets had a major impact on the overall UGV program plan. This budget reduction led to lack of funding for the TUGV EMD until FY97. It seems appropriate to develop new concepts to present to users to give them an idea about future weapon system opportunities. However, new regulations demand service and user requirements prior to the development of new concepts. "Moreover, future budgets will not allow new 6.3B programs to be initiated without a clear Service requirement" (DOD, 1993, p. 13). There must be a balance between the push of new ideas and the pull or demand from the user. This places a huge emphasis on effective and large-scale demonstrations of systems and capabilities. According to Geroski (2003), an inchoate demand exists when the end user verifies that a certain capability would be nice if it were available in the market to satisfy a need. Therefore, due to immature UGV technology, inchoate demand pulls out innovation and provides the direction for innovators to focus. Effectively, UGV users do not necessarily know what they need until they see something new and innovative. This creates a challenging balance in determining what system and capability should be developed.

4. 1994 Unmanned Ground Vehicle Master Plan

The 1994 UGVMP highlighted the goal of the joint robotics program (JRP), which is to field a family of first-generation UGVs for tactical operations and to coordinate the integration of technology among various JRP projects. The master plan makes a point to delineate which organizations are responsible for the UGV programs listed under the current UGV program.

Tactical UGV projects or TUGVs are the responsibility of the U.S. Army and USMC out of the Unmanned Ground Vehicles/Systems Joint Projects Office (UGV/S JPO). This office is also responsible for maintaining UGV requirements and the technical approaches being developed to meet said requirements. EOD projects are the responsibility of the Program Management Office for Explosive Ordnance Disposal. The development of the robotic excavation vehicle (REV) is carried out by the Air Force through the Airbase Systems Branch. Physical security projects are carried out by the Physical Security Equipment Management Office (PSEMO; DOD, 1994). In order to manage such a disbursement of agencies working on UGVs throughout the DOD, memorandums of agreement (MOAs) have been established to coordinate the sharing of technology and reduction in duplication efforts. The requirements that led to the solution for that year is shown in Table 9.

Table 9. Requirements Articulation 1994 UGV Master Plan

1994
Requirement
Border Control
Breaching
Countermine Operations
Environmental Cleanup
Explosive Ordnance Disposal
Logistics
Minefield Detection & Neutralization
NBC Detection and Laser Designation
Obstacle Detection
Physical Security
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
Remote Mine Clearance
TUGV - Supporting the Infantry
UXO
Threat/Conflict
Bosnian War (1992-1995)
Haiti (1994-1995)
Lessons Learned Desert Shield/Desert Storm (chemical weapons)
UGV Solution
Tactical Unmanned Ground Vehicle (TUGV)
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
NBC Detection and Laser Designation
Robitic Evacuation Vehicle(Rev) (renamed from RRR)
Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas)
Remote Ordnance Neutralization Device (ROND)/Remote Ordnance Neutralization System(RONS)(Initiated 1990)
Explosive Ordnance Disposal
Mobile Detection Assessment Response System - Exterior (MDARS-E) (Initiated 1992)
Reduce manpower by patrolling exterior of buildings and compounds in day, night, hot, cold, wet & dry conditions
Engineer Vehicle Teleoperation Capability (EVTC) (Initiated 1993)
Remote Mine Clearance
Breaching
Environmental Cleanup
**Focuses on lessons learned for Desert Shield/Desert Storm*
***Chemical weapons, demand for remotely operated mine-clearing tanks, autonomous guided weapons (force multiplier)*

This master plan draws on the recent conflicts of Desert Shield and Desert Storm to further justify the importance of UGVs. The plan calls to attention the fact that if troops faced an immediate chemical weapons threat, then a demand for remotely operated mine-clearing tanks and autonomous guided weapons could showcase their effectiveness in these conflicts keeping friendly casualties to a minimum and setting a new standard for future conflicts. The document reminds the reader that UGVs are a force multiplier and that they are a solution to all of the previously mentioned requirements.

Future recommended potential applications to increase combat effectiveness and personnel safety include RSTA, logistics, minefield and other obstacle detection, neutralization, and breaching, explosive ordnance disposal, physical security, and operations in contaminated environments. Environmental restoration of existing and closed defense sites is another use for UGVs (DOD, 1994). These are all worthwhile applications, but there are already ongoing programs that address these needs in the 1994 master plan.

Figure 33 depicts the 1994 UGV program as a whole. Since 1993, very little has changed. The MDARS-E program has shifted Milestone II about one quarter further into the future. The EVTC program has added a Milestone 0 expectation in FY95 and Milestone I/II achievement in FY97. The 1993 plan had no planned milestones. Lastly, the REV program was only scheduled through FY95 in 1993, but this has been extended out through FY98 in the latest master plan.

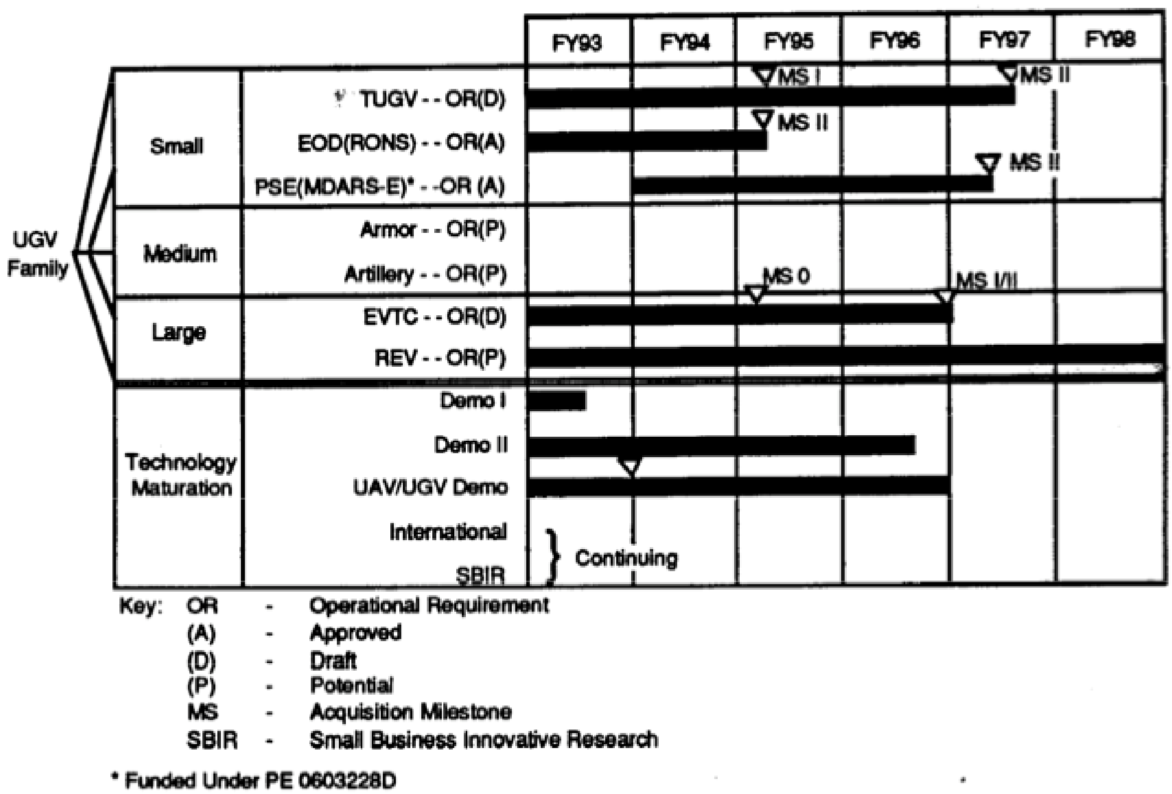


Figure 33. 1994 UGV Program Schedule (from DOD, 1994)

Planned funding for Advanced Systems Development (ASD) programs in 1994 is presented in Table 10. In 1993, the TUGV and EVTC funds were combined and in this year's plan, the funds were separated and each program given its own line. Both the TUGV and EVTC program received increased FY94 funds compared to what was planned in the 1993 plan, but then planned funds were down for FY95 and FY96 compared to the plan a year earlier. The REV program is the only other program with funding changes, demonstrating an increase in planned funds for FY95 and FY96 with all other years remaining the same.

Table 10. 1994 Planned Funding for ASD Programs ($M; from DOD, 1994)

UGV Type	Prior Years	FY94	FY95	FY96	FY97	FY98	FY99
TUGV	29.67	9.46	9.35	7.55	4.0[c]	0	0
EVTC	0.93	2.04	2.15	1.72	0[c]	0	0
REV	6.25	1.10[a]	1.90	1.90	2.35	1.85	1.05
RONS	4.80	1.50[b]	0.40[c]	0	0	0	0
Total	41.65	14.10	13.80	11.17	2.35	1.85	1.05

[a] In addition to the amounts shown, the Air Force budgeted $0.40 million in FY94.
[b] In addition to the amounts shown, the Services budgeted $0.40 million in FY94.
[c] Transitions to EMD in the indicated year. The Services have programmed funds.

a. TUGV from 1993 to 1994

The document lists the prototypes that have been developed and tested over the past several years; it is slightly different from the prototypes mentioned the year prior. The robotic all-terrain vehicle, which is the latest TUGV displayed is shown in Figure 34. The following are the 1994 TUGV systems (no information is provided about the systems that were present in 1993 and not 1994):

1. Surrogate Teleoperated Vehicle (STV)
2. Surveillance and Assessment Robot for GI Enhancement (SARGE)
3. Gecko
4. HMMWV based Technical Test Bed (TTB)
5. Robotic All-Terrain Vehicle (RATV)

Figure 34. Robotic All-Terrain Vehicle (RATV) (from DOD, 1994)

In all other prior year master plans, the TUGV program had its own enlarged schedule along with a separate schedule and funding table that displayed the OSD funding by year on the top funding row and the service funding on the lower row. This particular chart was eliminated in this year's master plan for the TUGV, but it is present for all other programs that are listed in the ASD planned funding table. This is interesting because the TUGV is the main effort program of the JRP, so one would assume access to more readily available information about this program.

Using the planned funding for ASD programs table, it is determined that TUGV funding increased during FY94 and is projected to decrease in FY95 and FY96 based on what was presented in the 1993 master plan. Figure 35 is the TUGV program schedule presented in 1994, which does not vary much from the 1993 program schedule. The only difference worth highlighting is a shift in the user evaluation schedule. In last year's plan, user evaluations were scheduled from FY94 to FY96, and in this year's plan, the evaluations are now planned to occur from FY95 to FY98. This is a significant shift, but it is likely designed to align better with technology maturation from DEMO II on existing UGV prototypes.

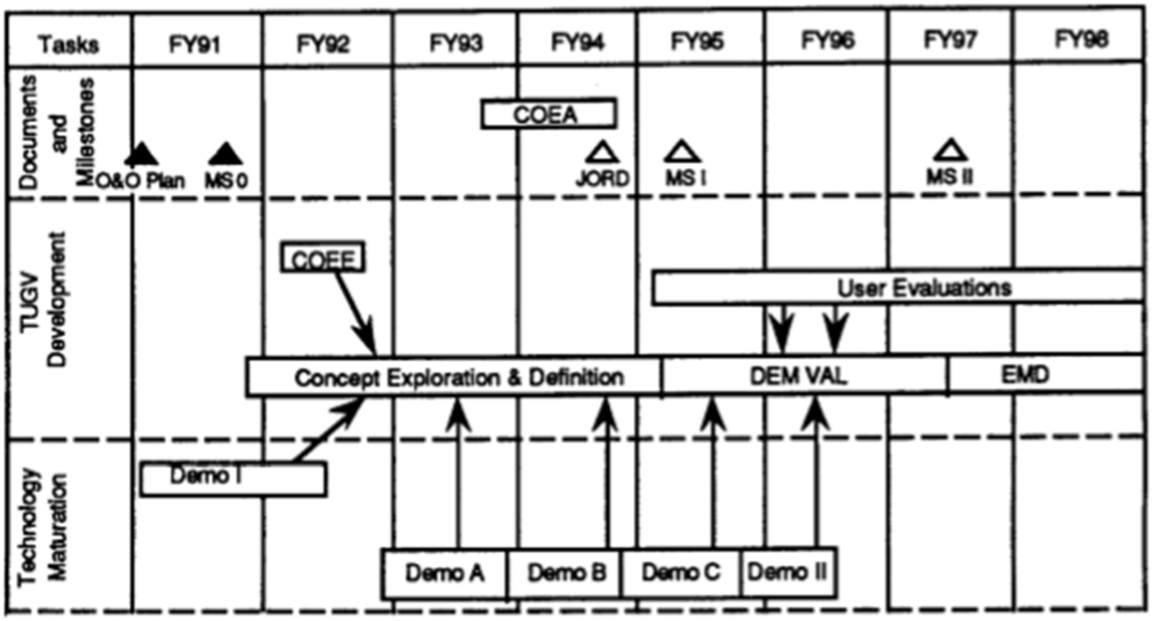


Figure 35. 1994 TUGV Schedule (from DOD, 1994)

b. RONS from 1993 to 1994

Figure 36 compares the remote ordnance neutralization system (RONS) schedule and funding from 1993 to 1994. All milestones for this program have shifted to the right by about three months with the exception of the planned Milestone II decision in FY95, which remained intact. The OSD planned funding did not change in the past year, but the service level funding increases every year from FY93 to FY98. The most interesting development for this program over the past year lies in the change of total number of expected RONS' acquisitions. In 1993, the plan was to acquire 200 total RONS' systems. In the 1994 master plan, only 90 RONS are planned for acquisition. The Army plans to acquire 52, the Marine Corps plans to acquire 32, and the Navy and Air Force each plan to acquire three vehicles. Information is not present to confirm, but it is assumed that the unit cost per system increased significantly when the overall number of systems for acquisition reduced.

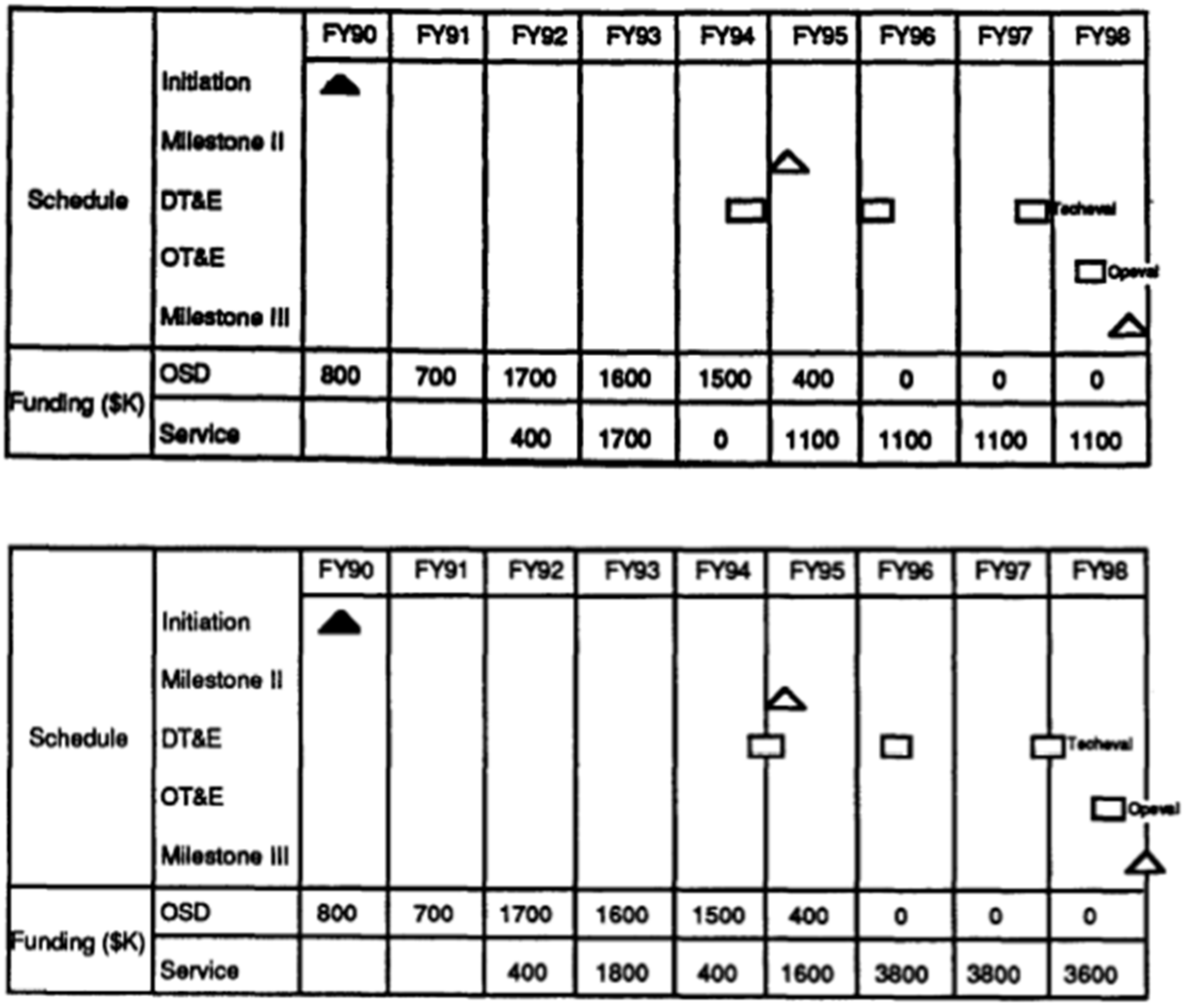


Figure 36. 1993 RONS Funding and Schedule Compared to 1994 RONS Funding and Schedule (from DOD, 1993, 1994)

c. REV from 1993 to 1994

According to the 1994 UGVMP, the REV program has made significant technical progress in that the vehicle is now capable of conducting "highly accurate, autonomous navigation and positioning in a pre-mapped (including obstacles) environment such as an airfield or a bombing range" (DOD, 1994, p. 26). The near-term plan for this program is to demonstrate the system's ability to autonomously remove/dispose of UXO. The program touts that "repetitive steps in the removal/disposal operation can be completed in 70 percent of the time required by onboard, at risk, operators" (DOD, 1994). If the demonstrations occur successfully, this is a significant achievement that could positively spill over to other UGV programs.

This document paints a very clear picture of the REV program and ensures that the reader understands that the REV is a system of systems. This is an early indicator of UGV system complexity and the challenges related to integration as the program expands.

> The overall area clearance system will consist of a mobile control center, an Autonomous Tow Vehicle (ATV) carrying a sensor array that locates the buried ordnance to be cleared, a robotic marking vehicle that marks detected UXOs, and a robotic excavator. (DOD, 1994, p. 27)

It is easy to view these vehicles as simple systems and to have difficulty understanding why autonomous operation cannot be readily achieved. When one looks at all of the components and interoperability that must occur within the system, it becomes more clear why achieving full autonomy is so complex.

The REV schedule and funding presented in the 1994 master plan is shown in Figure 37. There are a few changes from the year prior worth mentioning. On the schedule, Milestone I/II has moved forward to one year earlier, from FY97 to FY96. In the 1993 schedule, Milestone III was planned for FY98 and in the latest master plan Milestone III is no longer visible and the time line has been extended through FY00. From FY95 to FY97, OSD funding was increased for this program and extended another three years to FY00. Funding from the services also increased in all years from FY94 to FY97, but funding in FY98 went down.

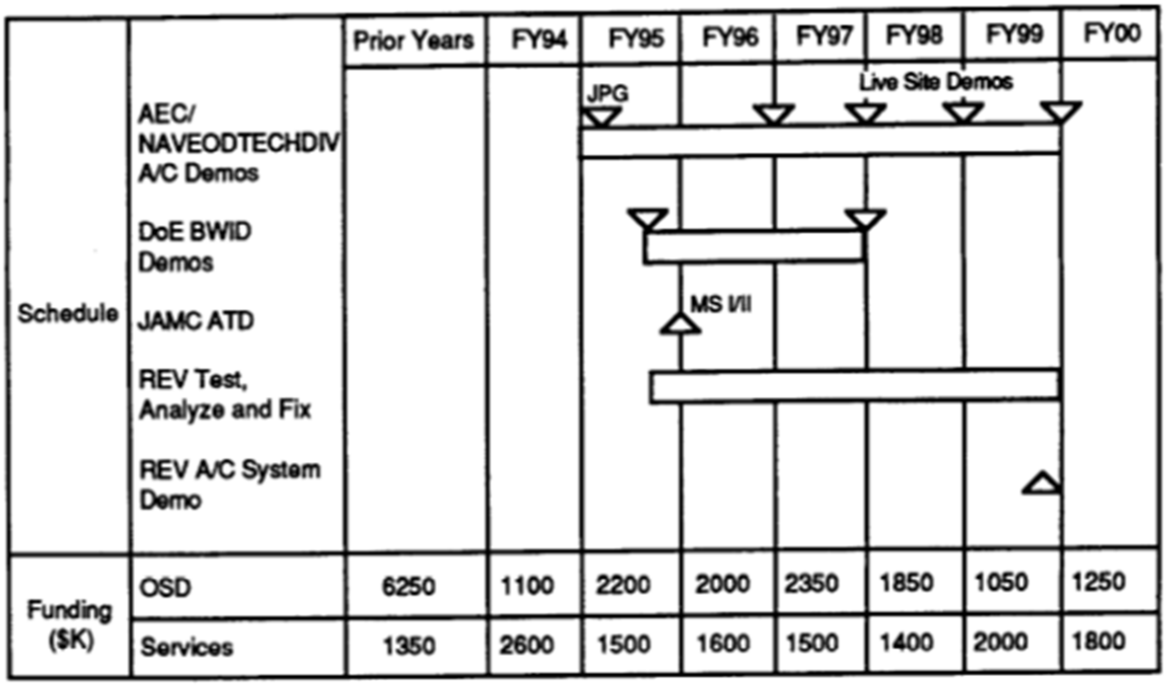


Figure 37. 1994 REV Funding and Schedule (from DOD, 1994)

d. EVTC from 1993 to 1994

In the 1993 master plan, the engineer vehicle teleoperation capability (EVTC) program did not have a schedule and the funding was lumped together in the TUGV program. In the 1994 document, the EVTC has its own schedule and the funding for the program is listed in planned funding for ASD programs presented in Table 10. Figure 38 is the first schedule presented for this program. Milestones I/II are planned for FY97 and Milestone III is planned for FY00. OSD funding of this program extends through FY96 since EMD will coincide with this funding taper and services assume the financial obligation of procurement.

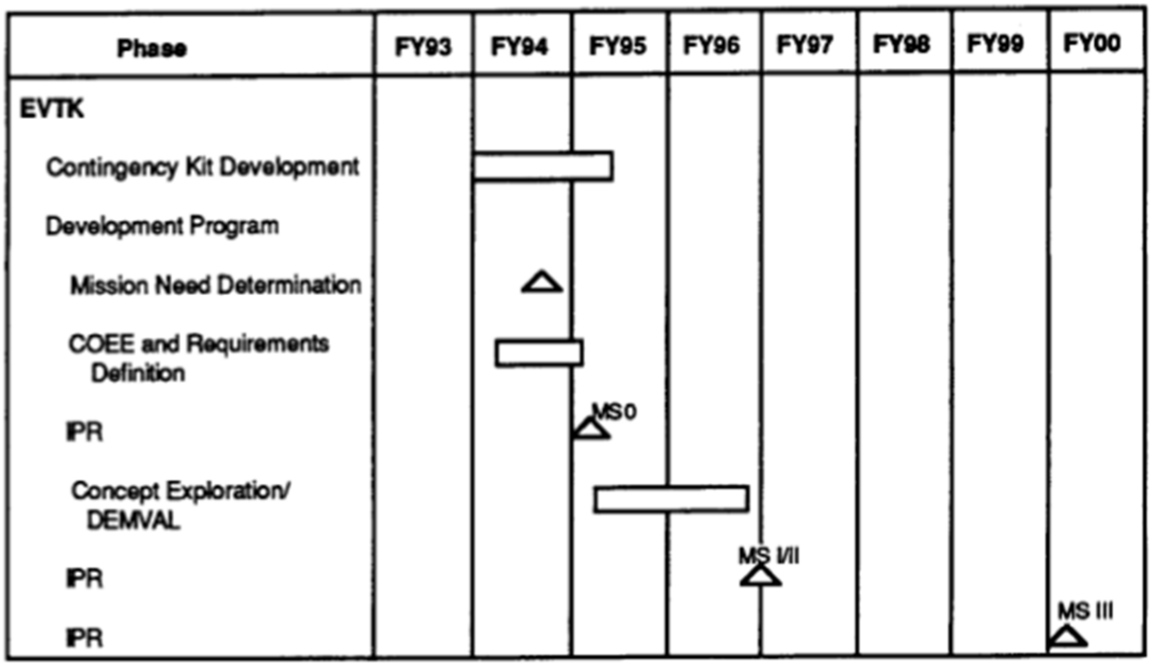


Figure 38. 1994 EVTC Program Schedule (from DOD, 1994)

e. DEMO II from 1993 to 1994

The 1994 master plan asserts that the success of the DEMO II plan has led to a need for further efforts to get UGVs in the hands of operational units and users for system evaluation and to discover further UGV uses and advancements that are not currently under consideration. The document explains the importance of getting UGVs to units so that personnel can develop an appreciation of the systems. It is critical for units to develop an understanding of how UGVs work, particularly highly autonomous UGVs and how they will interact with manned systems (DOD, 1994). This evaluation, feedback, and analysis can serve as the foundation for follow-on research and development at the conclusion of DEMO II.

The DEMO II schedule presented in the 1993 master plan has not changed at all in the past year, and in fact, DEMO A and DEMO B have concluded and are summarized in this document. The results of the two phases are presented in the following two paragraphs:

> The conduct of Demo A on 7 and 8 July 1993 successfully completed the first phase of Demo II. This phase integrated the basic mechanical and

> electrical components, automotive controls, color and infrared visual sensors, GPS, INS, odometry, and intervehicle communication that provide the foundation for autonomous navigation. Demonstrated research software, such as autonomous path following based on model and neural net approaches, was ported to the remoted vehicle. Vehicles built for Demo II use HMMWV platforms and are denoted as Surrogate Semiautonomous Vehicles (SSVs). (DOD, 1994, p. 34)
>
> Demo B, conducted in late June 1994, completes Phase 2. It demonstrated basic map management functions, single vehicle mission planning, off-road and on-road semiautonomous navigation, robust high-speed capability, landmark detection and identification, and rudimentary behavior for following rules on the road. (DOD, 1994, p. 34)

At this time, DEMO II is 50% complete and expected to conclude in 1996 with the lofty goal of demonstrating autonomous capabilities on UGVs. DARPA is still the lead agency of this effort and the end results are expected to deliver significant results that can benefit both military and civilian applications. DEMO II extends beyond autonomy and also encompasses system architecture, RSTA, high performance computing, and communication links.

f. MDARS-I and MDARS-E 1993 to 1994

In the 1993 master plan, the mobile detection assessment response system-interior (MDARS-I) depicted in Figure 39, receives no mention and the mobile detection assessment response system-exterior (MDARS-E) program, depicted in Figure 40, was described as a potential program, although it was listed on the UGV program schedule in Figure 33. At that time, the MDARS-E receives classification as an Operational Requirement and is categorized as an approved program with Milestone II planned for FY97.

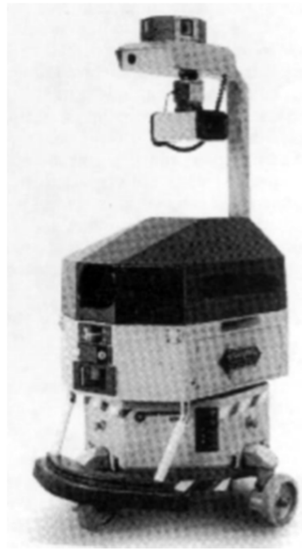


Figure 39. Mobile Detection Assessment Response System Interior (MDARS-I) Mobile Platform (from DOD, 1995)

Figure 40. Mobile Detection Assessment Response System Exterior (MDARS-E) Mobile Platform (from DOD, 1996)

The MDARS-I/E is a system that is designed to perform security inside and outside of military facilities such as large warehouses and depots. The system consists of multiple interior systems that patrol the facility and are controlled by one central control console. The system's purposes are to prevent loss of DOD equipment, reduce risk to DOD personnel, and to reduce intensive manpower requirements associated with security patrolling of such facilities (DOD, 1994). The MDARS presents an opportunity to reduce manpower costs significantly at locations where it is utilized. It is also in the process of sharing technology with the TUGV program to maximize the technology transfer between the two programs. The MDARS program is managed by the physical security equipment management office (PSEMO).

In the 1994 master plan, the MDARS-I and MDARS-E are both presented in Appendix A of the document and each program has its own schedule. In this year's UGV overall program schedule, presented in Figure 33, there is only the MDARS-E on the program schedule with no program funding data provided. Figure 41 depicts the MDARS-I program schedule. The key events that are planned for this system include Milestone I/II decisions in FY96 and Milestone III in FY98. The plan is to procure 48 total MDARS-I systems at a rate of 12 systems per year from FY99 to FY02. The MDARS-E schedule is depicted in Figure 42 with Milestones I and II planned for FY97 and Milestone III in FY99. The procurement plan calls for 18 total systems at a rate of six systems per year from FY00 to FY02.

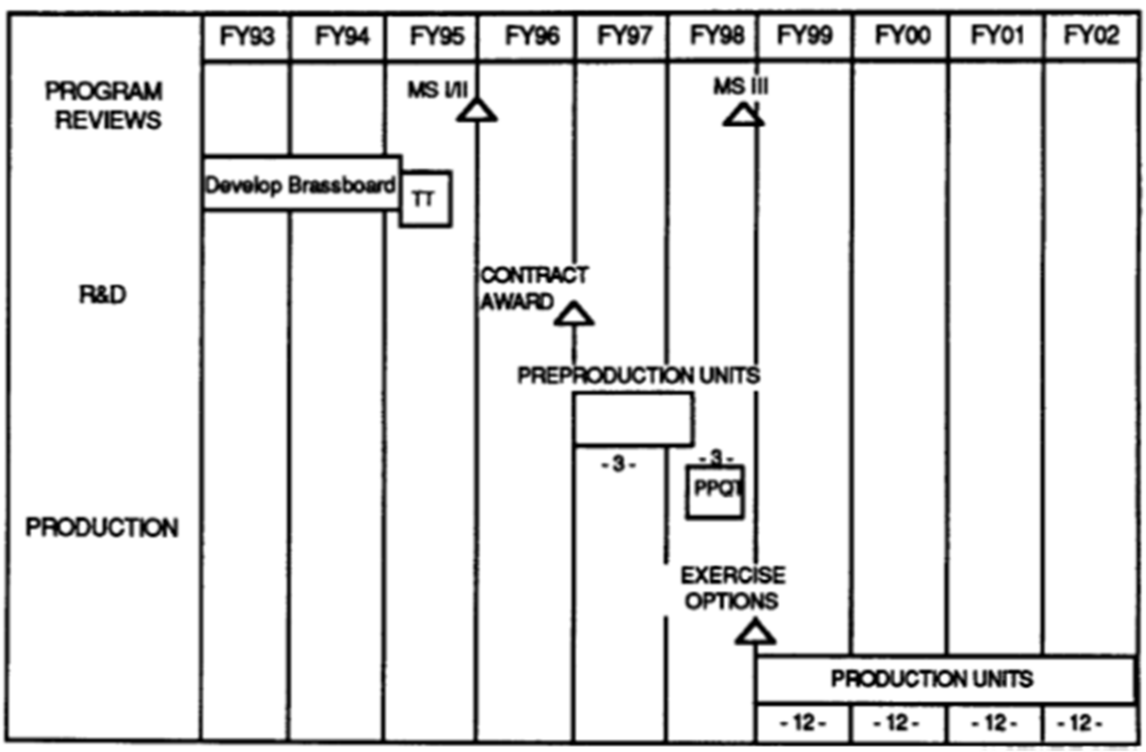


Figure 41. 1994 MDARS-I Program Schedule (from DOD, 1994)

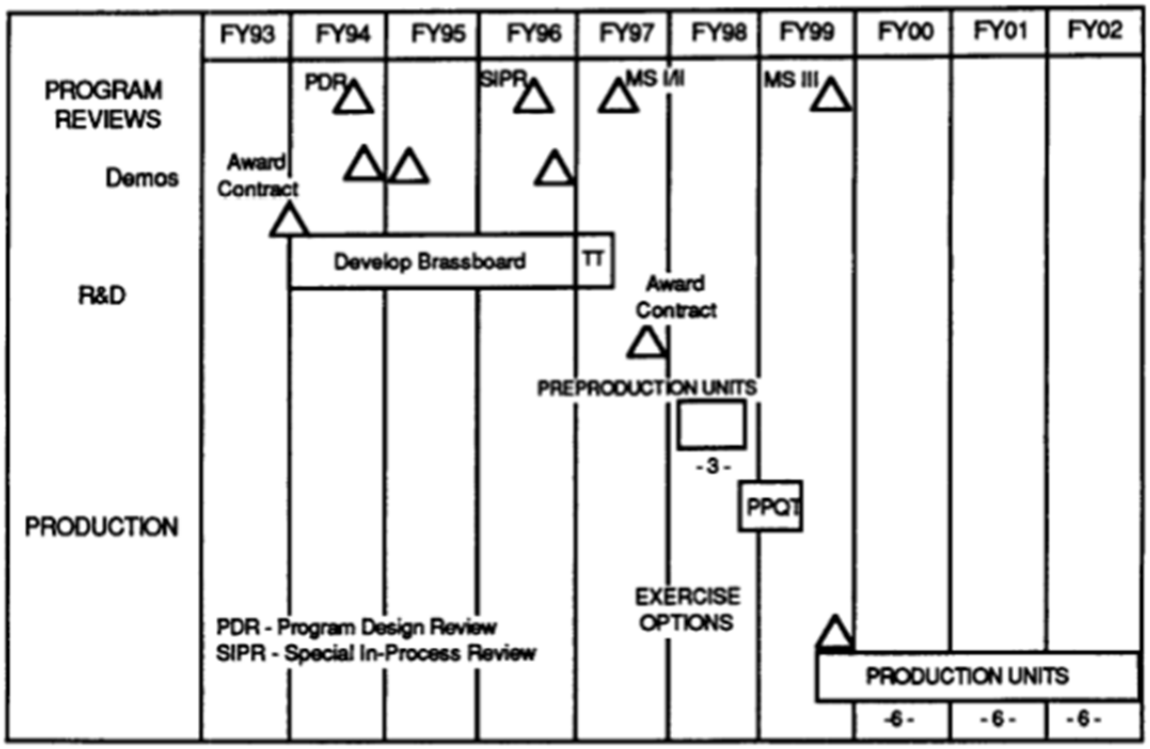


Figure 42. 1994 MDARS-E Program Schedule (from DOD, 1994)

g. *Conclusion*

In just a few short years, the UGV program has expanded significantly with movement in the program schedules and funding over the years, confirming budget uncertainty predicted in earlier master plans. At this point, no programs are in the EMD phase, so no UGVs have been fielded to operational units. DEMO I has concluded and technology transferred to DEMO II, which exists as the ongoing technology maturation thrust for the UGV program.

5. 1995 Unmanned Ground Vehicle Master Plan

In this master plan, the goal of the JRP has changed and now aims "to develop and field a family of unmanned ground vehicle systems for a range of military applications in accordance with user requirements" (DOD, 1995, p. 1). This change focuses UGV systems development on user requirements; the document presents significant highlights for the program, covered in greater detail later in this section. The schedules for all programs shift to the right in this master plan, and one new program is introduced by the name of joint architecture for unmanned ground systems (JAUGS). The requirements that led to the solution for that year is shown in Table 11.

Table 11. Requirements Articulation 1995 UGV Master Plan

1995
Requirement
Breaching
Countermine Operations
Develop & Field family of UGVS for range of military applications IAW user requirements
Environmental Cleanup
Explosive Ordnance Disposal
Firefighting, handling & loading of aircraft munitions, multiple UXO during clearing operations
Logistics
Minefield Detection & Neutralization
NBC Detection and Laser Designation
Obstacle Detection
Physical Security
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
Remote Mine Clearance
TUGV - Supporting the Infantry
UXO
Threat/Conflict
Bosnian War (1992-1995)
Haiti (1994-1995)
UGV Solution
Tactical Unmanned Ground Vehicle (TUGV)
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
NBC Detection and Laser Designation
Robitic Evacuation Vehicle(Rev) (renamed from RRR)
Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas)
Remote Ordnance Neutralization Device (ROND)/Remote Ordnance Neutralization System(RONS)(Initiated 1990)
Explosive Ordnance Disposal
Mobile Detection Assessment Response System - Interior/Exterior (MDARS-I/E) (Initiated 1992)
Reduce manpower by patrolling exterior of buildings and compounds in day, night, hot, cold, wet & dry conditions
Added security inside military facilities such as large warehouses and depots
Engineer Vehicle Teleoperation Capability (EVTC) (Initiated 1993) (renamed VTC)
Remote Mine Clearance
Breaching
Environmental Cleanup
Joint Architecture for Unmanned Ground Systems (JAUGS) (Initiated 1995)
Develop common hardware/software open achitecture to ensure intraoperability (vehicle to vehicle)
Interoperability (data communications in command, control, communications, computers & intel (C4I) result in cost savings

From the 1994 master plan to the 1995 master plan, there are significant changes to all programs on the UGV program schedule. The first noticeable change presented in Figure 43 is that the UGVs are no longer represented by size—small, medium, and large.

Instead, the name of the program is simply presented. The robotic excavation vehicle (REV) program has added the letter S, for System, to the end of its name. Milestones I/II shift at least one year into the future for all programs and the MDARS-E Milestone III shifts to the right by about one year as well.

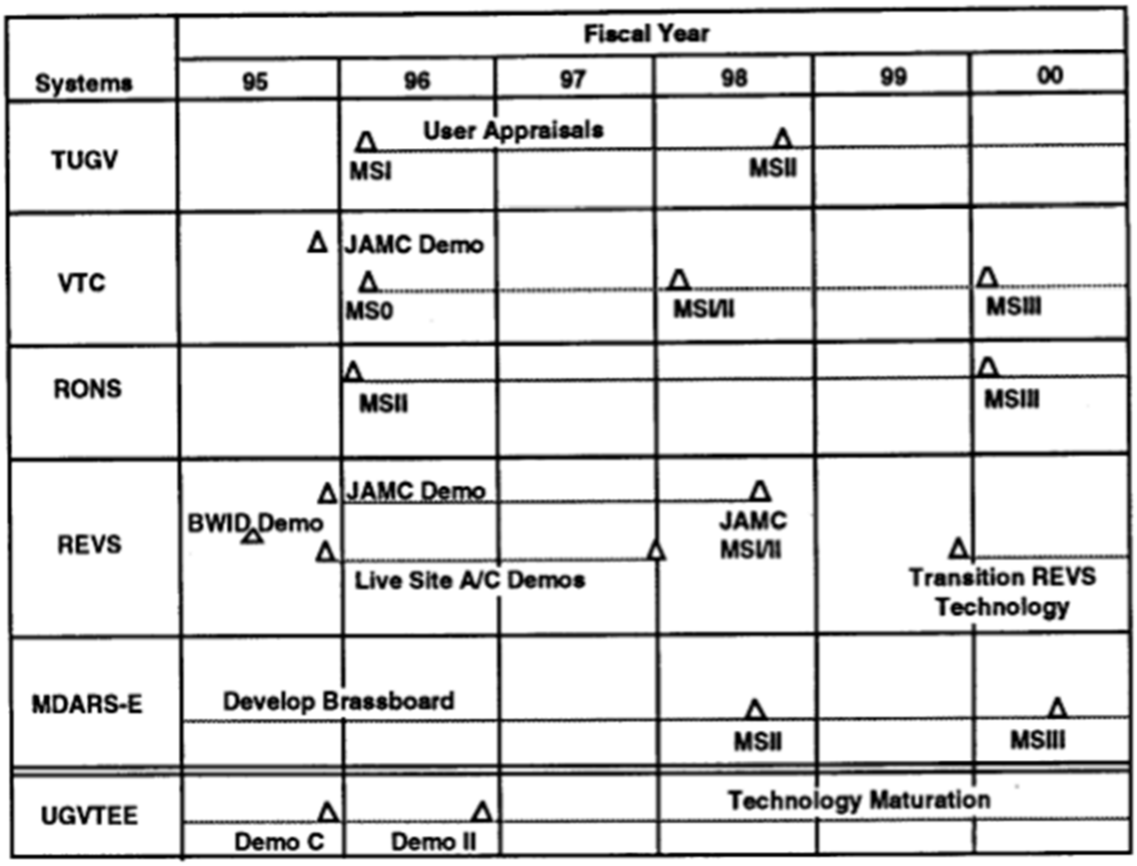


Figure 43. 1995 UGV Program Master Schedule (from DOD, 1995)

Table 12 is the 1995 master plan funding for ASD programs and from the year prior there are numerous funding changes. The TUGV funding increases in all years except for FY96, where it is down. The VTC program experiences a decrease in funding in FY95 but then FY96 and FY97 are increased from the year prior. The REVS program also experiences a decrease in FY95 followed by four years of increased funding through FY99. Lastly, the RONS program receives increased funding in FY96 and FY97.

Table 12. 1995 Funding for ASD Programs ($M; from DOD, 1995)

ASD Program	FY95	FY96	FY97	FY98	FY99	FY00	FY01
TUGV	10.0	7.2	12.8	17.5[c,d]	18.2	19.0	19.8
VTC	2.0	2.5	3.0	0	0	0	0
REVS	1.4[a]	2.5	3.5	3.0	3.0	3.0	3.0
RONS	0.4[b]	0.4[c]	0.4	0	0	0	0
Totals	13.8	12.6	19.7	20.5	21.2	22.0	22.8

a The Services and DoE are funding $6.4M in FY95 and $5.5M in FY96.
b The Navy is funding 550K to complete advanced system development.
c Transitions to EMD in the indicated year. The Services have programmed funds.
d The RSTA version of TUGV expects to enter EMD in FY98. Funds shown in FY98-FY01 are for other potential projects in the TUGV family.

This master plan presents the first management structure for the entire UGV program and for the UGV/S JPO. The organizational structures are presented in Figures 44 and 45. This graphical representation of the organizations gives a good understanding of the disbursement of each program throughout the DOD.

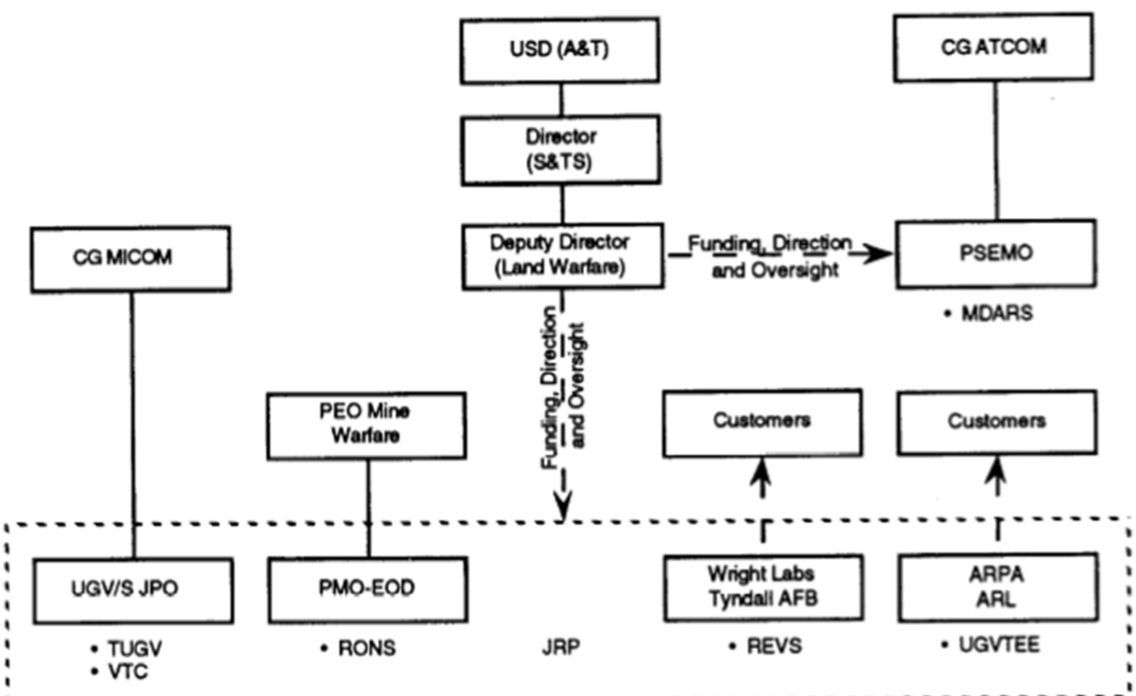


Figure 44. Management Structure for Unmanned Ground Vehicle Programs (from DOD, 1995)

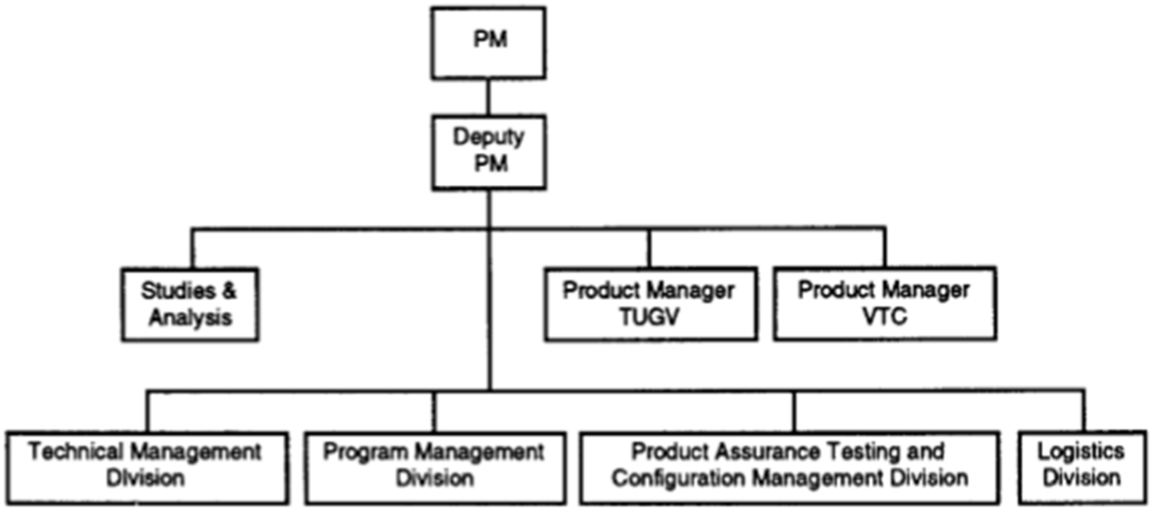


Figure 45. Unmanned Ground Vehicles/Systems Joint Project Office Organization (from DOD, 1995)

a. TUGV from 1994 to 1995

In the past year, several accomplishments were made within the tactical unmanned ground vehicle (TUGV) program. First, a formal operational requirements document (ORD) was approved by Training and Doctrine Command (TRADOC) in 1995. Several vehicles were also delivered to serve as test vehicles and the SARGE vehicles were delivered to users to help develop concepts for operational employment of the system and to help refine the requirements. The delivered tactical test beds (TTBs) are intended for engineering development and for the integration of RSTA payloads. Lastly, Gecko UGVs were delivered for the purpose of developing and evaluating computer-aided vehicle teleoperation (DOD, 1995). In the 1994 master plan, there were five TUGV systems that were highlighted, and, at this time, the program focuses on the three aforementioned. There is no mention of the robotic all-terrain vehicle (RATV) in this document, but the surrogate teleoperated vehicle (STV) is discussed briefly. The STV was used during an evaluation in 1992 that was observed by the French and the French went on to purchase four STVs of their own (DOD, 1995). The plan does not specify whether the French purchased new STVs or STVs that the U.S. government once owned. In either case, the STV is not recognized as a focal system in the 1995 master plan.

The TUGV program schedule compared to the schedule in 1994 is shown in Figure 46. Milestone I for this program shifted about one year into the future and Milestone II moved more than a year further into the future. Additionally, user appraisals were previously scheduled for four years and this appears to be decreased by one year.

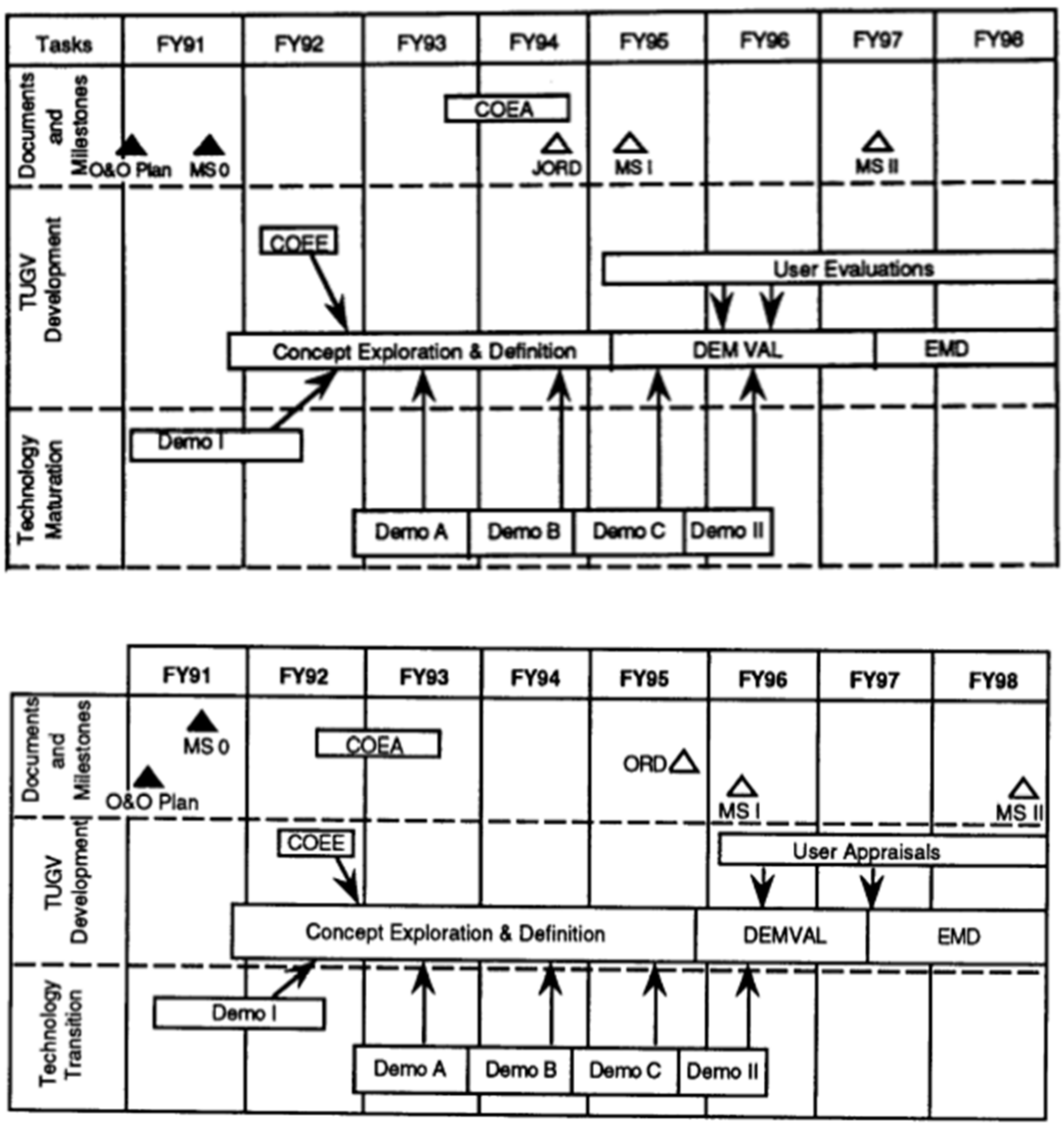


Figure 46. 1994 TUGV Program Schedule Compared to 1995 TUGV Program Schedule (from DOD, 1994, 1995)

b. RONS from 1994 to 1995

No major accomplishments for the RONS program were reported in this year's master plan. For the second year in a row, the Army has reduced the number of planned systems from 90 to 88 total systems. The schedule for this program is presented in Figure 47, and another slippage of key milestones into the future can be seen. The planned Milestone II date has shifted one year into the future from FY95 to FY96. The technical evaluation, operational evaluation, and Milestone III decisions all have also shifted one year into the future when compared to the schedule presented one year earlier.

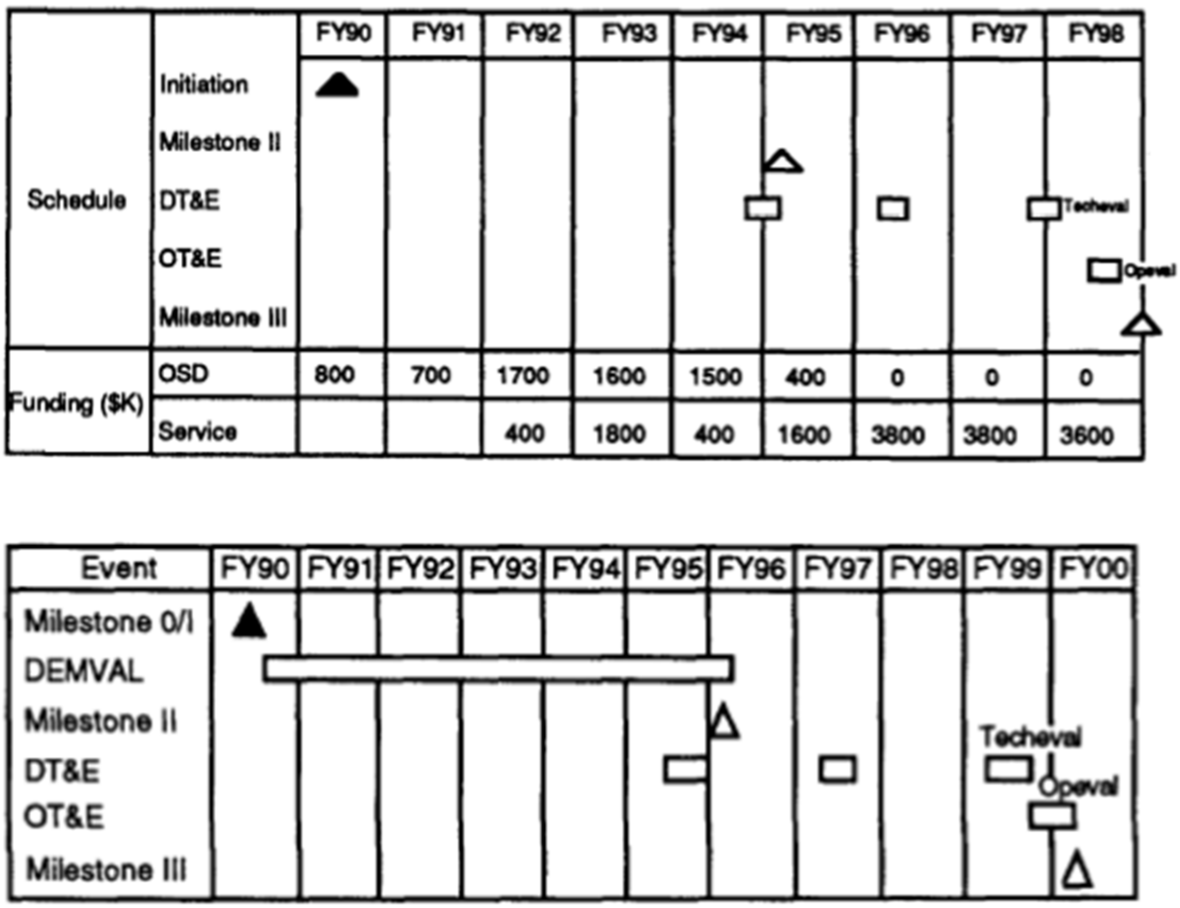


Figure 47. 1994 RONS Program Schedule Compared to 1995 RONS Program Schedule (from DOD, 1994, 1995)

c. REV/REVS from 1994 to 1995

Equipping the robotic excavation vehicle system (REVS) with a sensor, successfully demonstrated the REV's capability of removing buried UXO from known sites. Once able to navigate to the site and autonomously locate and extract the hazard, the REV could conduct and complete its mission. In the past year, an autonomous tow vehicle (ATV) was developed, and its purpose was to house the sensors that would locate the UXO. A first generation autonomous navigation system was developed for the REVS (DOD, 1995). In the coming year, through the support of DEMO II, the REVS would conduct a live test where the system would demonstrate its autonomous capability in an uncontrolled geological environment. The success of this program could provide significant advantages in the area of mine clearing and environmental restoration after the closure of DOD training areas. These systems will not only be useful to the DOD, but also to civilian contractors likely to conduct clearing operations as needed.

The 1995 REVS program schedule is shown in Figure 48. The only notable change on this schedule from the year prior is that Milestone I/II has shifted about one and a half years into the future.

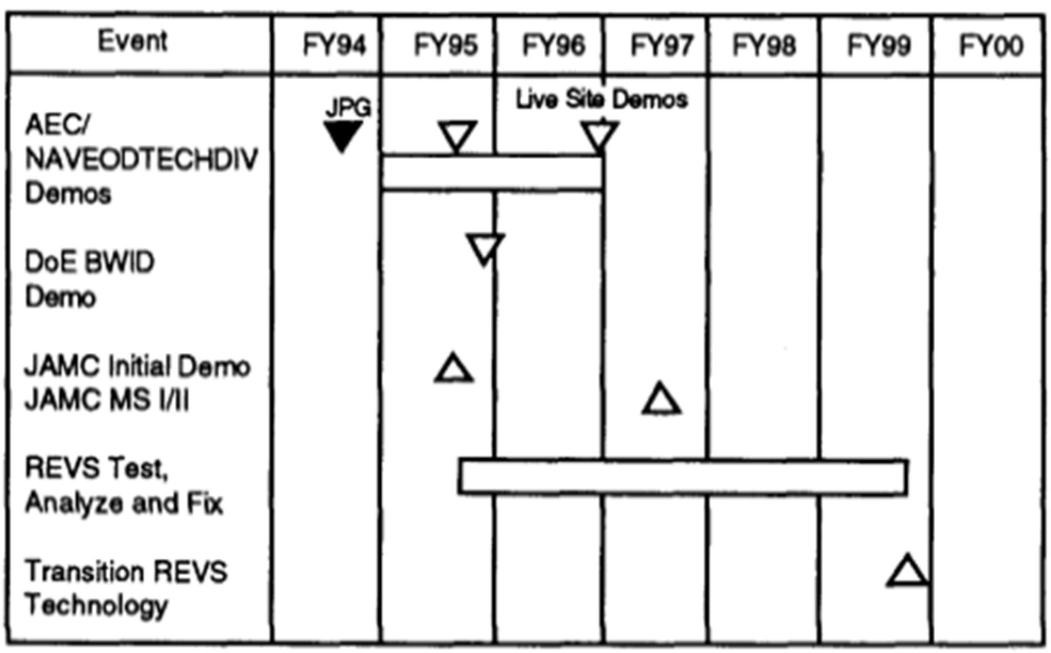


Figure 48. 1995 REVS Program Schedule (from DOD, 1995)

d. EVTC/VTC from 1994 to 1995

In the past year, the EVTC dropped the E for Engineering from its name, and it is now the vehicle teleoperation capability (VTC). At this time this kit was fitted onto a military issued five-ton truck with successful results. Based on this accomplishment, six more kits were delivered to the U.S. Army Engineer School so that the same conversion could be attempted on a mine detection vehicle. These kits were also successfully demonstrated on D-7G bulldozer and M-1 tank chassis (DOD, 1995). Because operating in a minefield or in the breach of a combat operation is one of the most dangerous places for a human to operate, this results in a significant capability on a large military vehicle. Furthermore, by being able to breach and reduce obstacles remotely, this advancement is seen as having a positive, desirable impact on modern combat if it can be successfully implemented within the force.

While the accomplishments of this program are impressive, Figure 49 displays the schedule slippage of this program from what was planned the year prior. Milestones 0, I, and II have all shifted one year further into the future from what was previously planned.

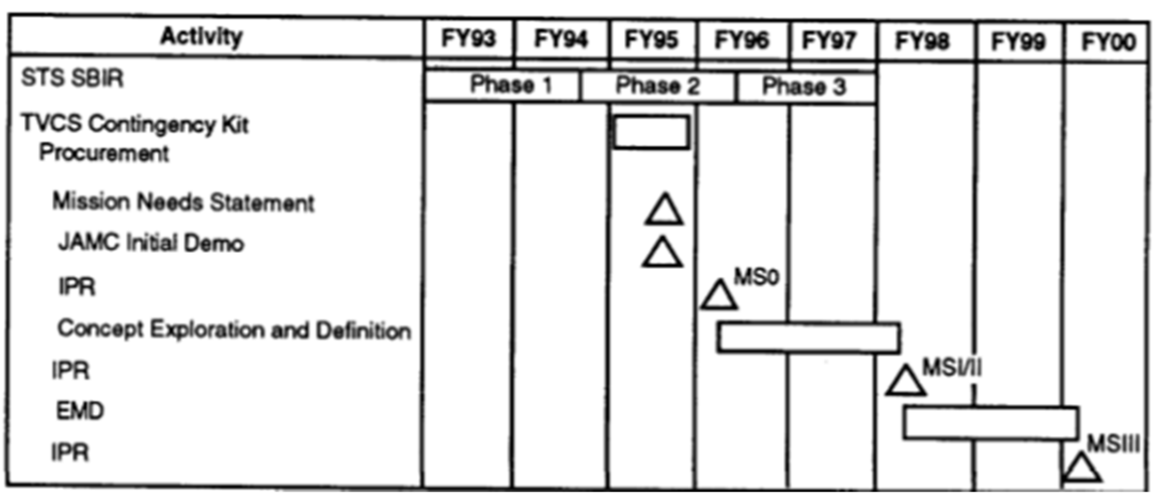


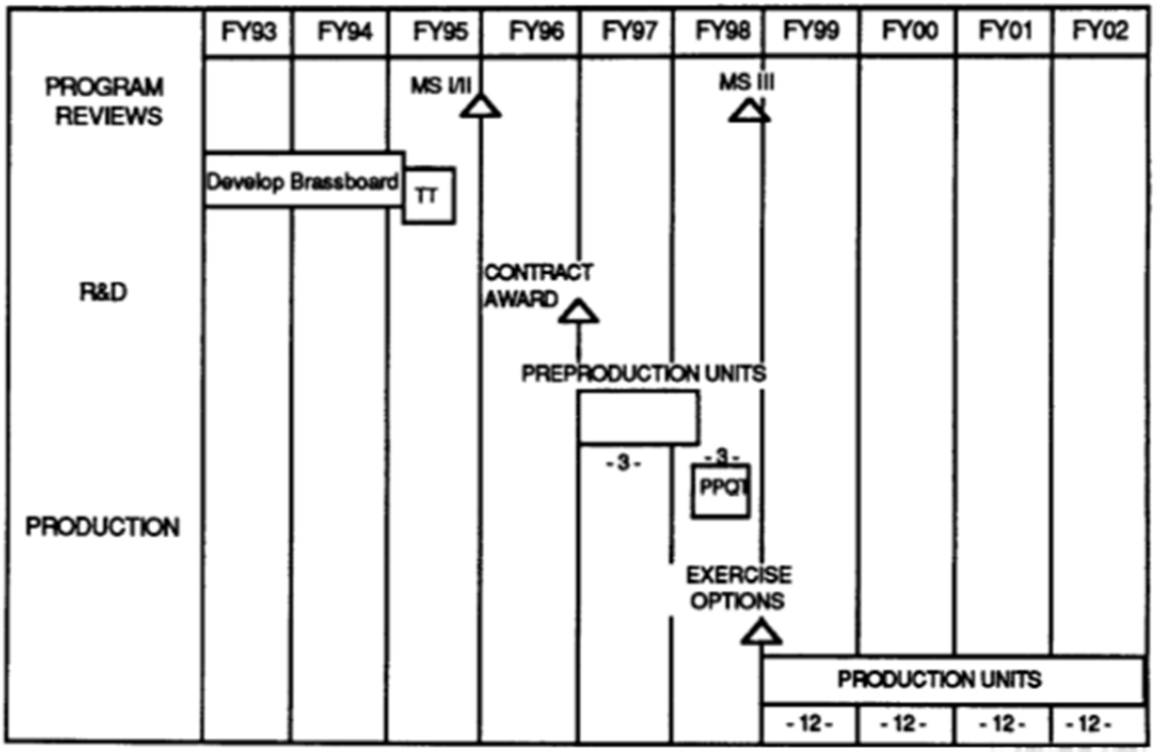
Figure 49. 1995 VTC Program Schedule (from DOD, 1995)

e. DEMO II from 1994 to 1995

DEMO II appeared to make some significant developments in the past year that could have huge impacts on future UGVs. DEMO C, the third phase of the program, was completed and "it demonstrated control of two UGVs simultaneously, semiautonomous navigation, negative obstacle detection, and RSTA on the move" (DOD, 1995, p. 2). During this phase, a semiautonomous vehicle was controlled via a satellite communication link, and a technology transfer plan was developed to ensure that progress made in this program is transferred to other UGV programs in a timely manner (DOD, 1995). While these accomplishments are worthy of praise, the DEMO II program concludes at the end of 1996 and successful demonstration of highly autonomous operations is not yet discussed and appears to be a concept that will not be realized in the foreseeable future.

f. MDARS-I/E from 1994 to 1995

In the past year, an MDARS-E prototype was developed. The MDARS-I schedule from 1995 compared to the 1994 schedule is shown in Figure 50. Milestones II and III have slipped further to the right by about one year. The planned contract award and production have also shifted further right by about six months each. The production time line for 1994 was four years, but now it is a three-year plan. Finally, the quantity to be acquired is no longer presented, making it difficult to determine if the acquisition number remains at 48 MDARS-I units.



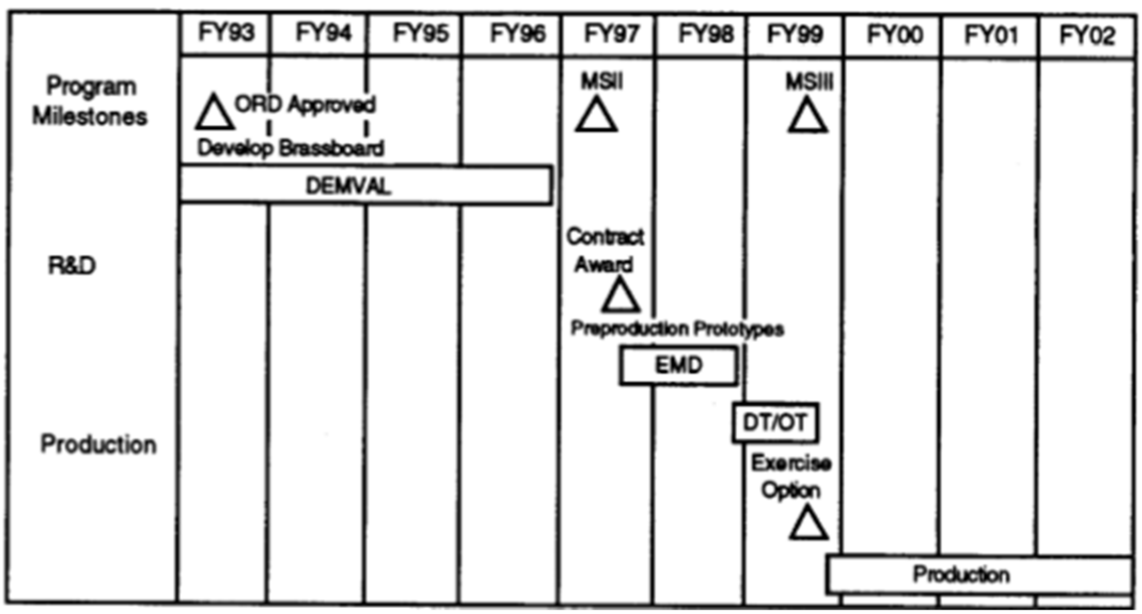


Figure 50. MDARS-I Schedule from 1994 Compared to MDARS-I Schedule from 1995 (from DOD, 1994, 1995)

The MDARS-E likewise experiences much of the same as its sister system. All milestones mentioned and key program events shift into the future by at least six months for each event. Figure 51 compares the 1995 MDARS-E schedule to the 1994 MDARS-E schedule. Again, the unit procurement removal from this schedule makes determination that 18 MDARS-E will still be acquired in future years difficult.

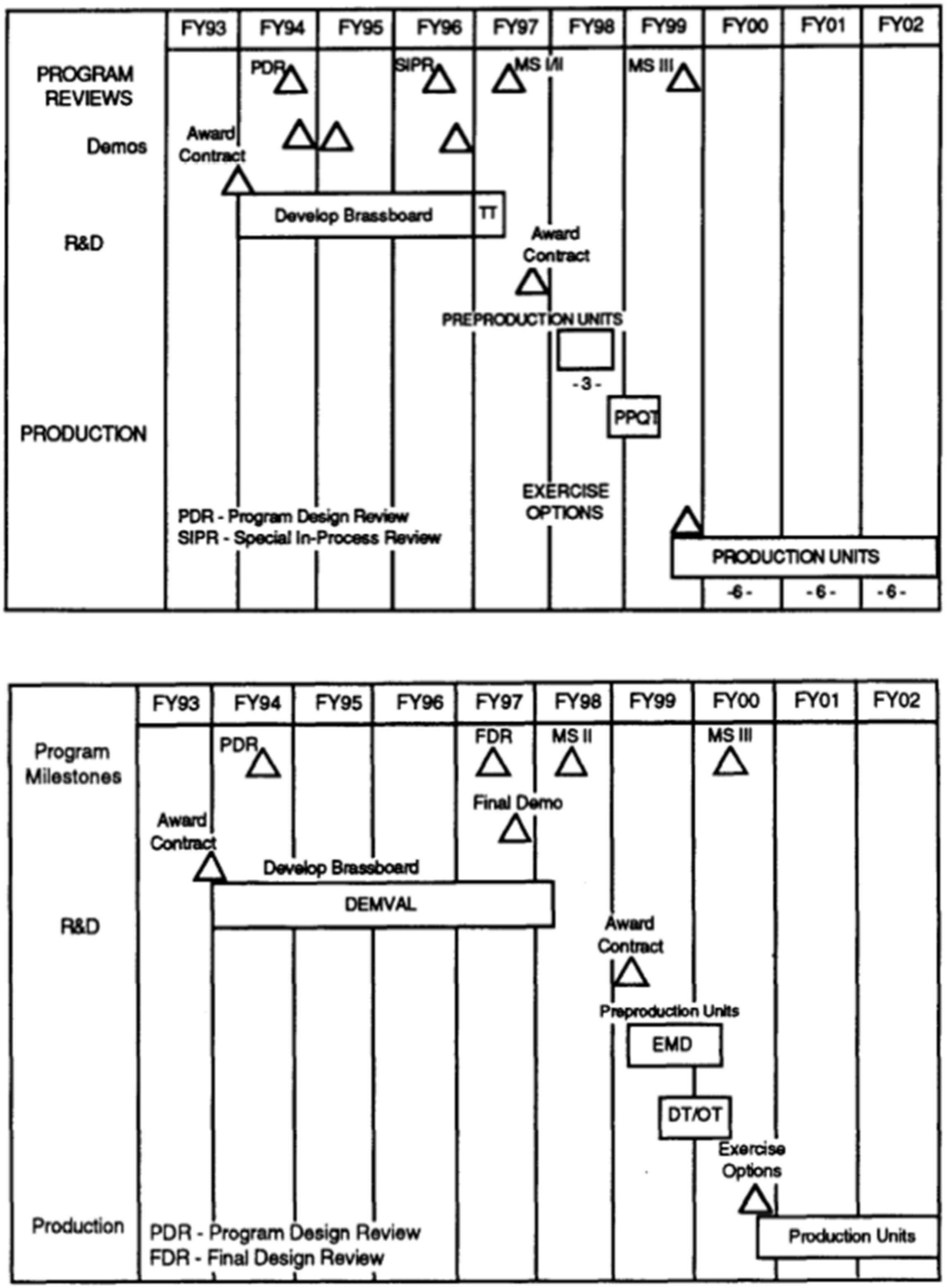


Figure 51. 1994 MDARS-E Schedule Compared to 1995 MDARS-E Schedule (from DOD, 1994, 1995)

g. JAUGS 1995

In 1995, the joint architecture for unmanned ground systems (JAUGS) program is the newest addition to the list of UGV programs. This program is one of the JRP investment focuses moving into the future and its purpose is “to develop a common hardware/software open architecture to ensure interoperability (vehicle to vehicle) and interoperability (data communications in the command, control, communications, computers, and intelligence [C41] global domain) on UGV systems resulting in cost savings to the user” (DOD, 1995, p. 1). Since its inception, the JAUGS program has adopted a concept that ensures disciplined development that supports the program objective. The JAUGS schedule for 1995 only is shown in Figure 52. This program remains significant as efforts to standardize architecture become more prevalent, especially as technology rapidly evolves over time.

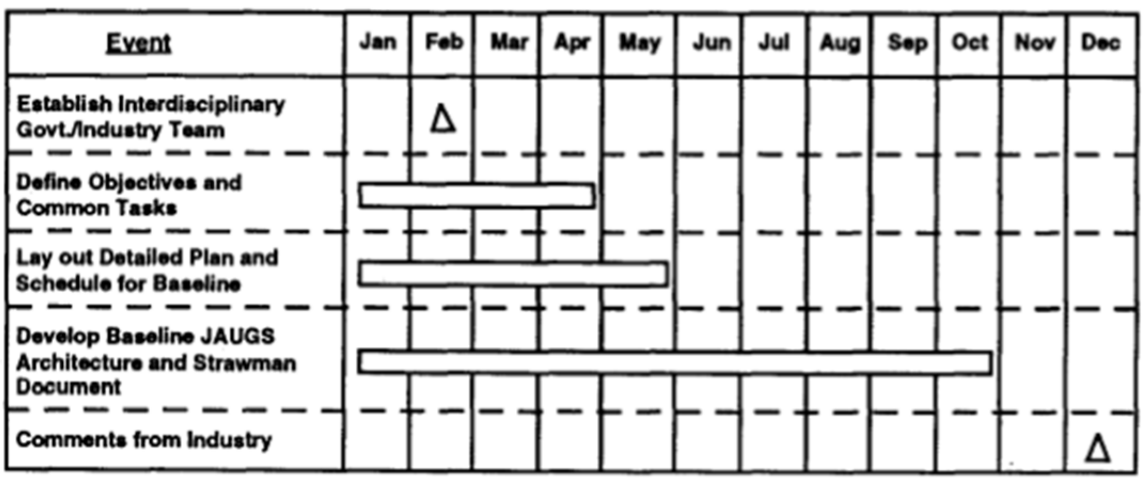


Figure 52. 1995 JAUGS Schedule (from DOD, 1995)

h. Conclusion

The 1995 master plan effectively highlighted all of the accomplishments that each program made in the past year. A lot of technological progress is evident in the UGV program, but autonomous operations remain a long way off. Disconcerting, however, are changes to each of the program schedules over the past year. As the years go by, the milestones appear to move further into the future and delivery of systems to operational units appear distant. Identifying delays in the schedules remains one of the goals of this paper and can be further investigated by looking at several unknowns such as budgetary issues beyond the control of the program managers, immature technology, and other less important issues not evident at this time.

This document also highlighted some emerging UGV capabilities that have not been presented in other documents and that sound like reasonable uses for UGVs. One potential use of UGVs exists in the task of firefighting as well as the handling and loading of munitions of aircraft. Another potential use is a system that gathers multiple UXO during clearing operations. All of these uses provide an opportunity to remove humans from risk to accomplish a very relevant mission.

6. Summary from 1991 to 1995

The goal of this project is to track key programs that originate with the establishment of the overall Unmanned Ground Vehicles program. The following programs are the focus of this research: TUGV, RONS, REVS, EVTC, and MDARS. Analysis of program performance is presented after 1995, 2000, and 2004. The analysis concludes with a summary of the full program schedule and funding from 1991 to 2004.

a. UGV Program Funding 1991 to 1995

Figure 53 displays the overall UGV funding from 1991 to 1995. The TUGV funding trends upward each year, which lends credence to it being the premier program each year. REVS and RONS funding does not show a distinct pattern other than validating budget uncertainty. A reduction in funding leads to a slippage in schedule, which is not necessarily the fault of the program manager but prevents delivery of useful systems to users in a timely manner.

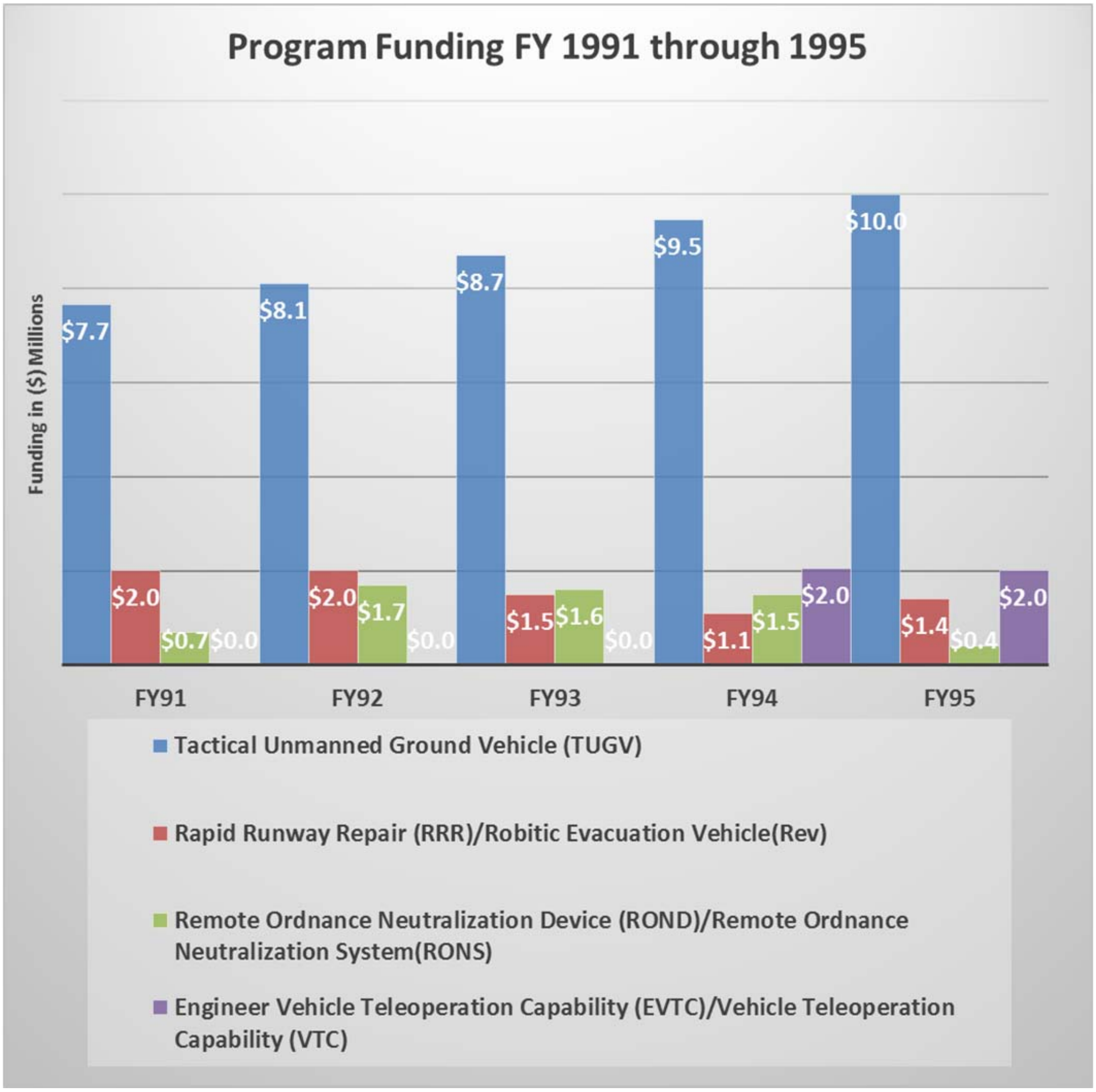


Figure 53. UGV Program Funding Comparison FY 1991–1995 (after DOD, 1991, 1992, 1993, 1994, 1995)

b. Tactical Unmanned Ground Vehicle 1991 to 1995

The change to the TUGV schedule from the first one presented in 1991 to the most recent presented in 1995 is shown in Figure 54. In 1995, Milestone I is not yet achieved and was originally planned for FY94 along with Milestone II in the 1991 master plan. Milestone II is now planned for FY98, which was the Milestone III date in the 1991 plan. At this point, Milestone III is not present in the schedule. This suggests that in 1991, the DOD expected to field TUGVs to users in 1998 and now is uncertain when the fielding will occur. While the schedule slips, the funding towards the TUGV program continues to rise as depicted in Figure 55.

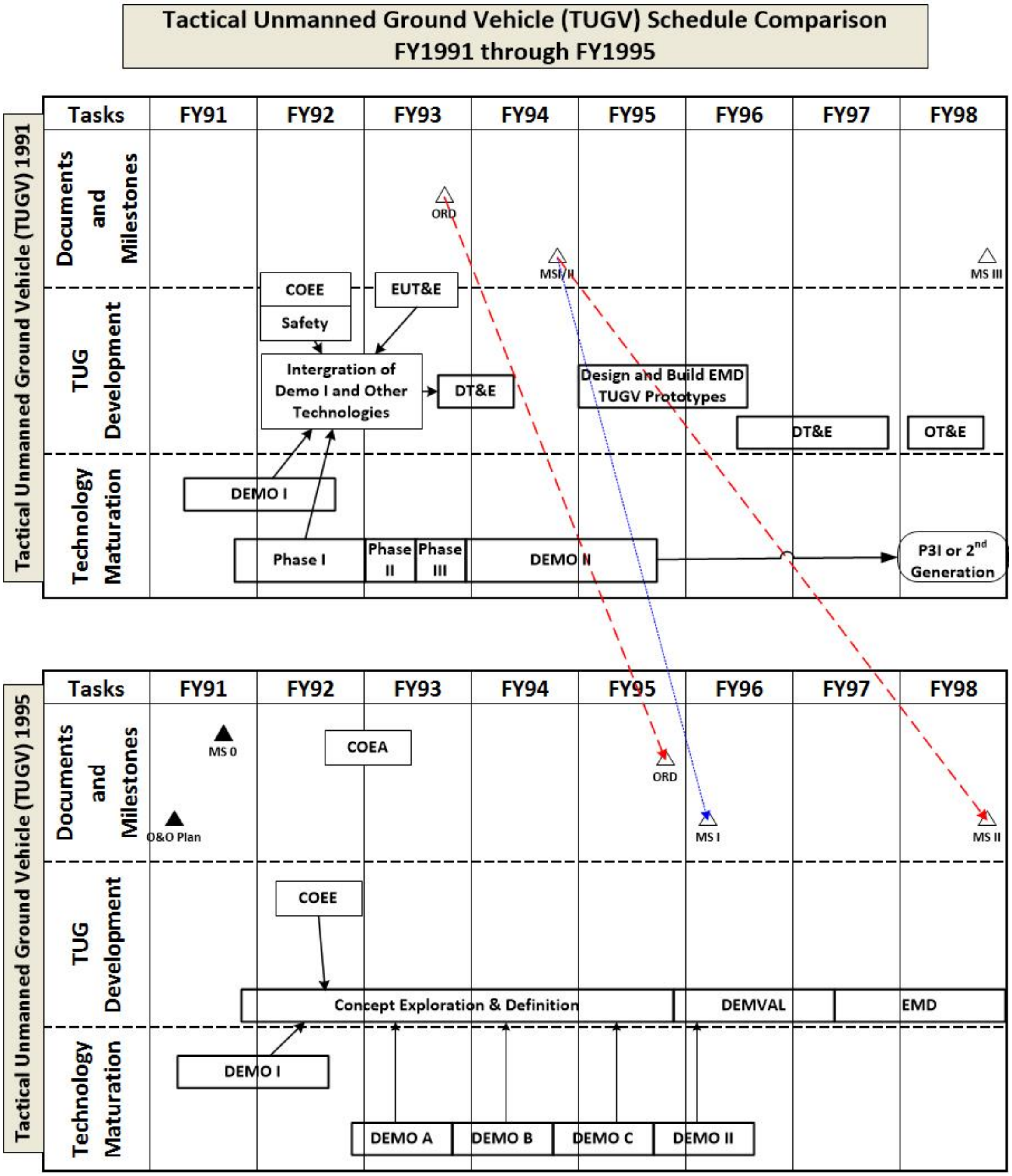


Figure 54. TUGV Schedule Comparison 1991–1995 (after DOD, 1991, 1992, 1993, 1994, 1995)

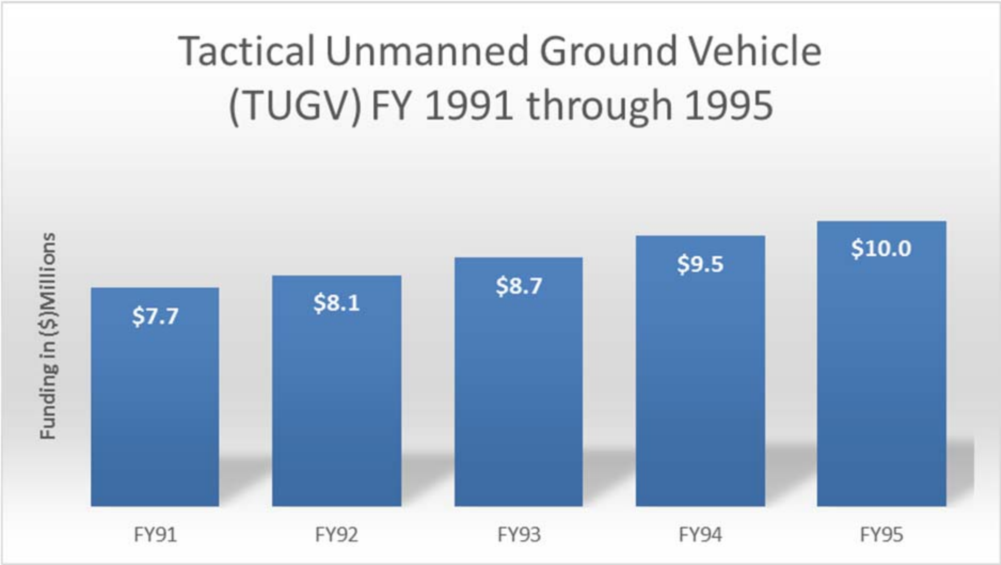


Figure 55. TUGV Funding Comparison 1991–1995 (after DOD, 1991, 1992, 1993, 1994, 1995)

c. RONDS/RONS from 1991 to 1995

From 1991 to 1995 RONS experiences a schedule slippage of two years depicted in Figure 56 for Milestones II and III. Essentially, all scheduled activities slip about the same amount of time for this program. The funding depicted in Figure 57 rose significantly and stabilized for a few years, tapering off significantly in 1995. This is interesting because at this point in time, the program is not in Milestone II and must be challenging for a program manager to successfully run the program with such a drastic budget cut.

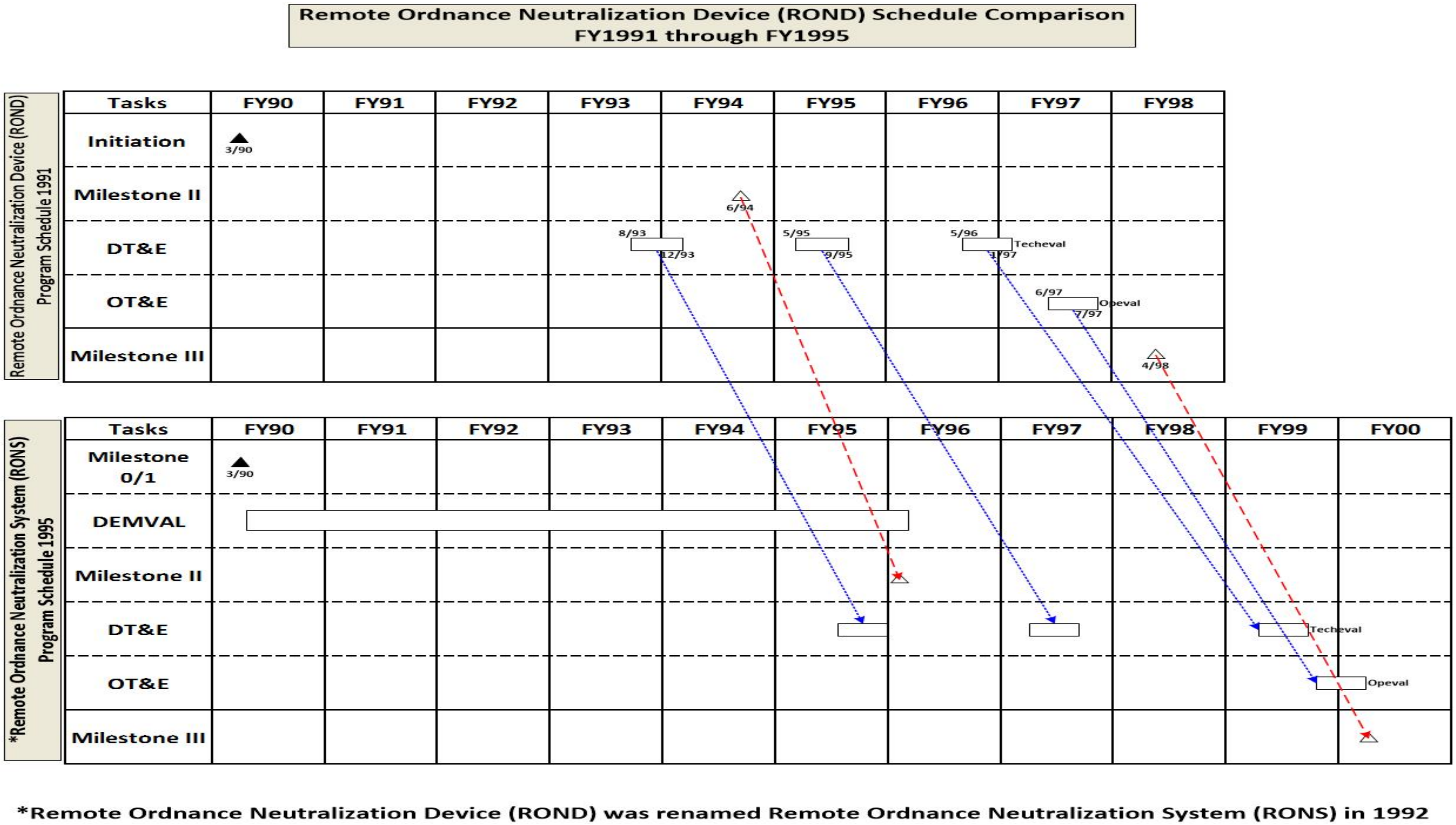


Figure 56. ROND/RONS Schedule Comparison 1991–1995 (after DOD, 1991, 1992, 1993, 1994, 1995)

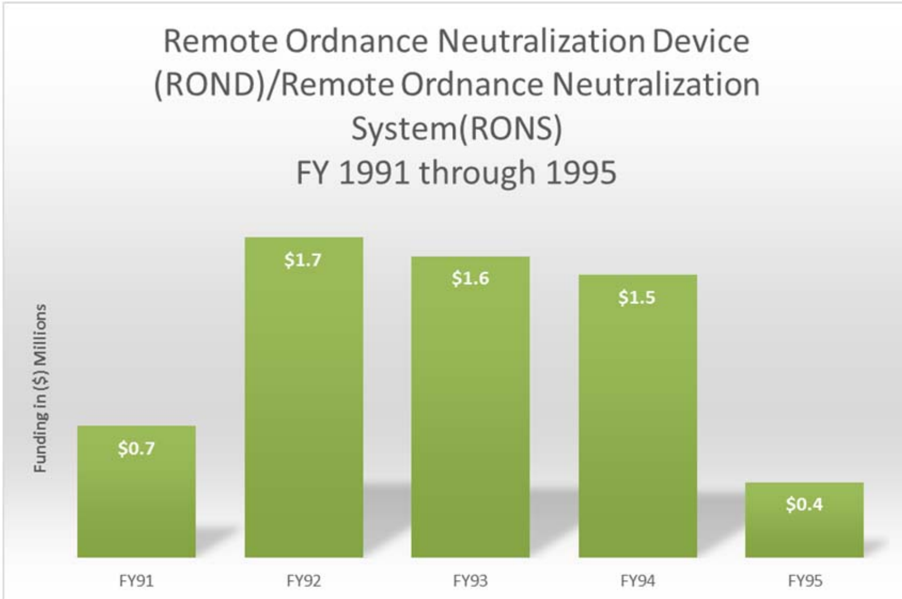


Figure 57. ROND/RONS Funding Comparison 1991–1995 (after DOD, 1991, 1992, 1993, 1994, 1995)

d. RRR/REVS from 1991 to 1995

The REVS experiences a similar situation as the TUGV. In 1991, this program was the RRR, but after the collapse of the Soviet Union, the requirement changed from runway repair to range clearance. Milestone II for the RRR was planned for FY94 and never occurred; the program became the REVS, and Milestone II is now planned for FY97. RRR had a planned Milestone III in FY97 but changed, and under the REVS program, Milestone III is no longer visible on the schedule as depicted in Figure 58. The program funding from 1991 to 1995, depicted in Figure 59, declined rapidly after the collapse of the Soviet Union. A new demand for this program likely salvaged this technology and transformed it into a system to meet an emerging requirement.

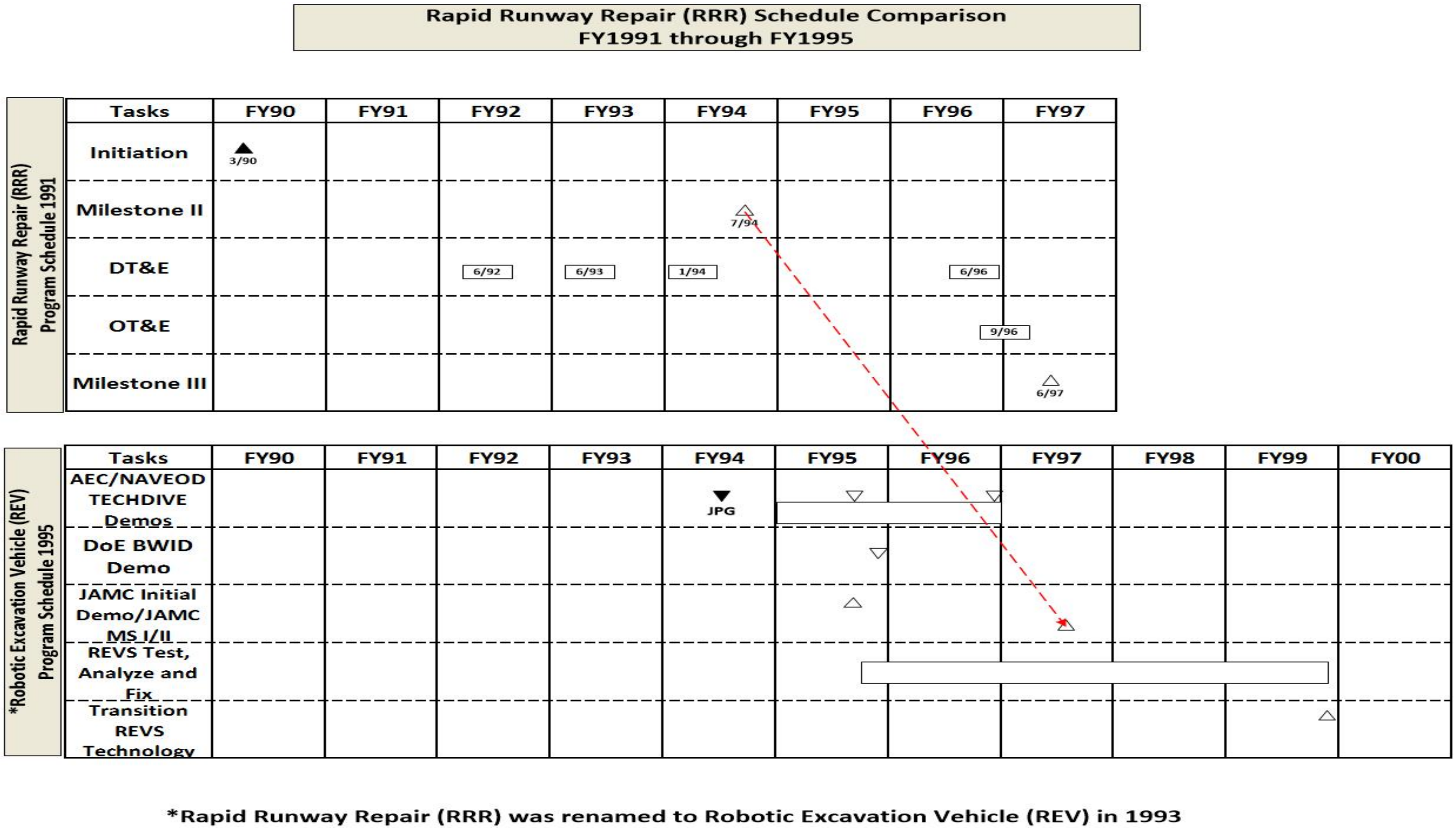


Figure 58. RRR/REV Schedule Comparison 1991–1995 (after DOD, 1991, 1992, 1993, 1994, 1995)

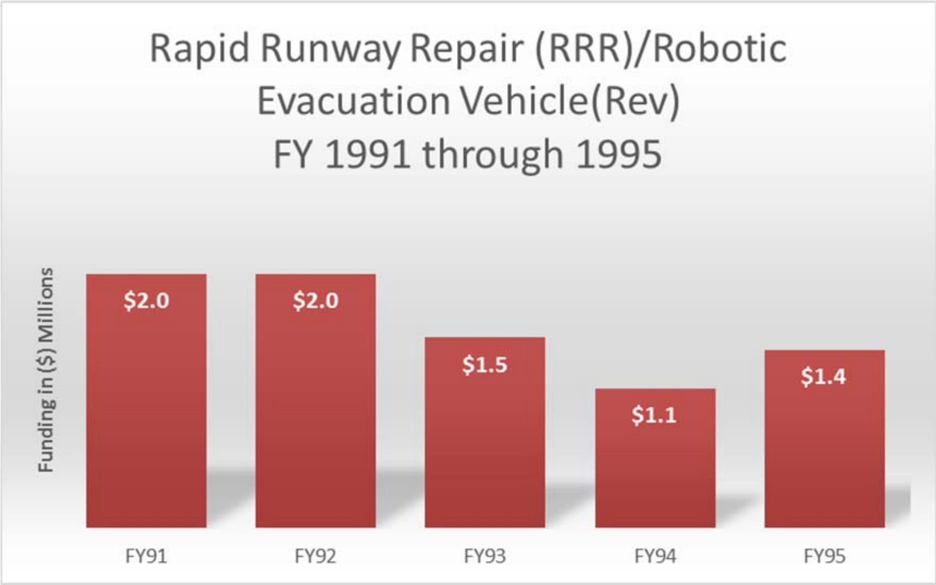


Figure 59. RRR/REV Funding Comparison 1991–1995 (after DOD, 1991, 1992, 1993, 1994, 1995)

e. EVTC from 1994 to 1995

The EVTC program is relatively new, so only two years of schedule and funding are presented, as depicted in Figures 60 and 61. In a short time, the schedule is impacted significantly as Milestones 0, I, and II both shift into the future by more than one year. Basically, Milestone 0 is not achieved at this point in time. The funding appears to be stable, so the challenged schedule is likely attributed to technology hardships associated with making a man-operated vehicle functional in an unmanned mode.

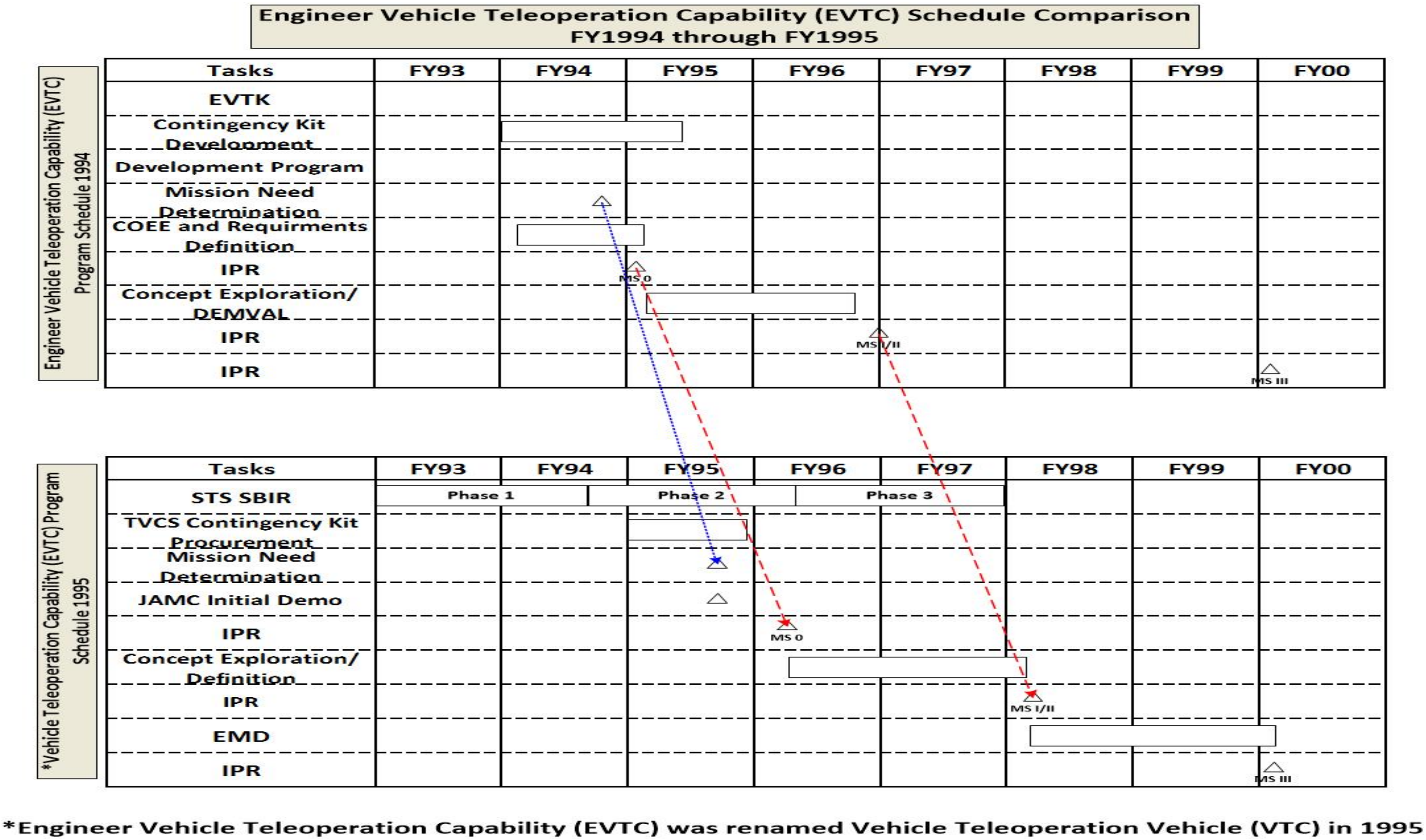


Figure 60. EVTC/VTC Schedule Comparison 1995–1996 (after DOD, 1994, 1995)

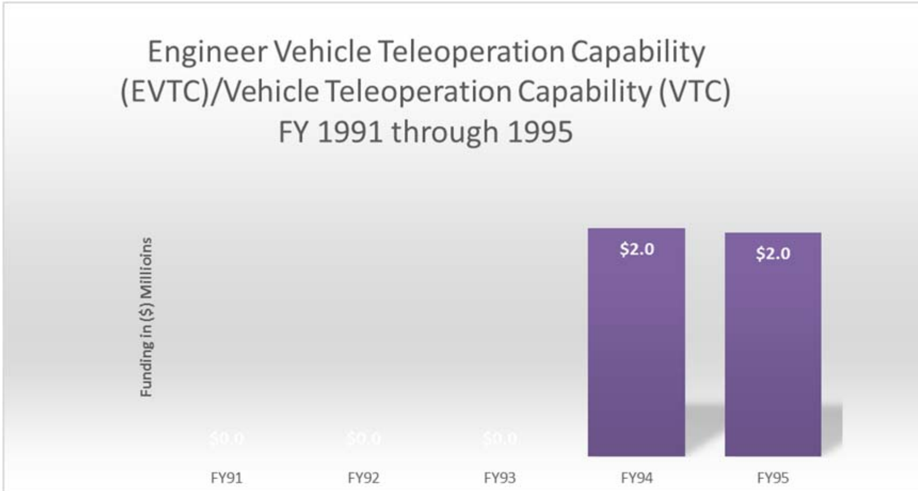


Figure 61. EVTC/VTC Funding Comparison 1994–1995 (after DOD, 1994, 1995)

f. MDARS-E from 1994 to 1995

The MDARS-E program was first reported in 1994, so only two years of schedule information is provided. No funding data for MDARS-E is available or presented in any of the present or future master plans. Milestones II and III slipped one year into the future from the 1994 to the 1995 master plan, as depicted in Figure 62. The 1994 master plan presented production unit quantities but was not carried to the 1995 master plan.

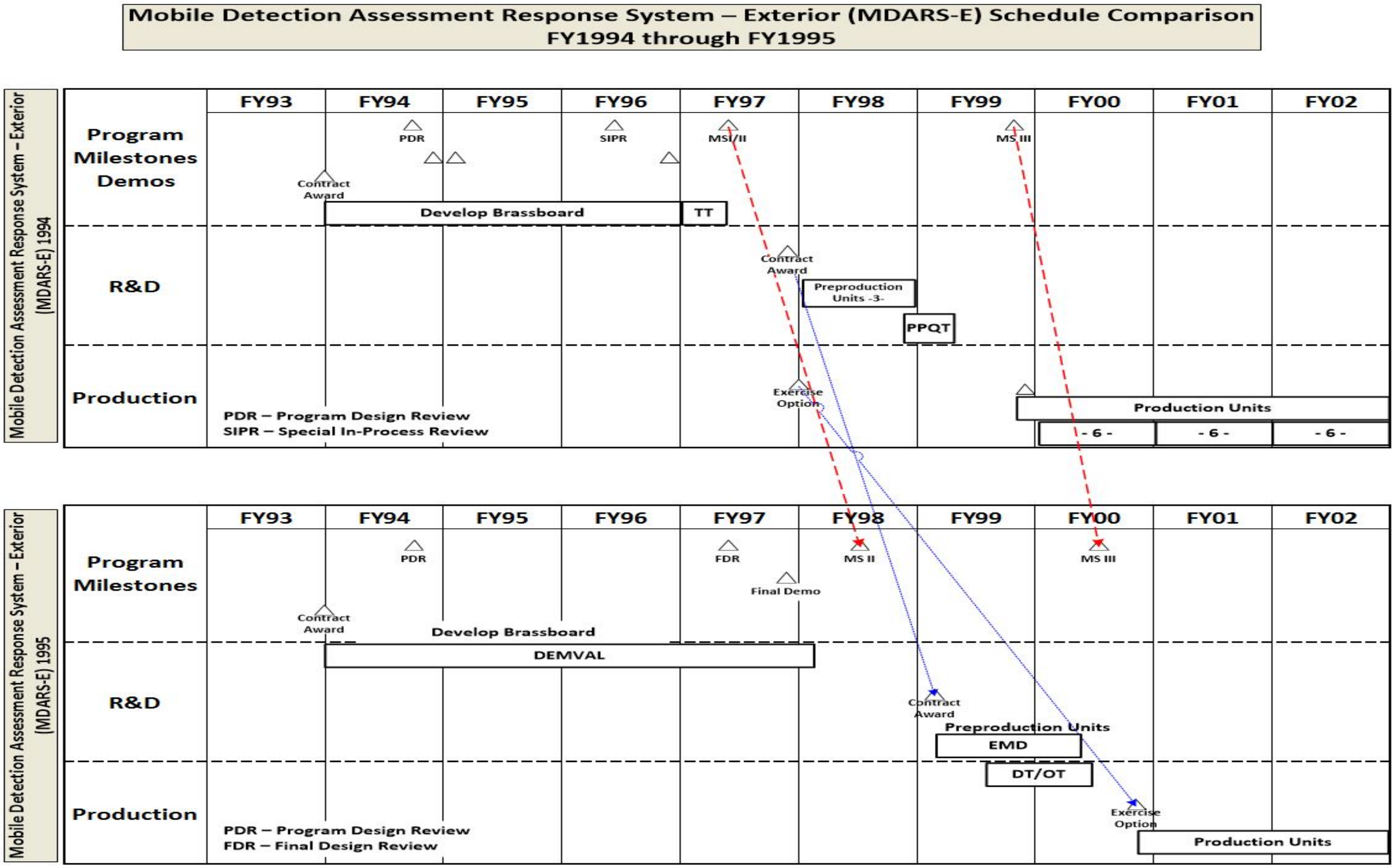


Figure 62. MDARS-E Schedule Comparison 1994–1995 (after DOD, 1994, 1995)

g. DOD and UGV Funding Comparison 1991–1995

While conducting research, an assumption was made that UGV funding would align with the DOD budget. It was believed that if the DOD budget increased, UGV funding would increase, or if the DOD budget decreased, UGV funding would also decrease. After analyzing Figure 63, it was determined that no correlation exists between the DOD and UGV budget. During several years, the budgets are inverse of each of each other, meaning that one is increasing while the other is decreasing. This chart is displayed at each summary and at the conclusion of the analysis to present the two funding charts from 1991 to 2004. The researchers' assumption is that the UGV budget is based on its level of priority against all other budget activities. As a researcher interested in the topic, it is easy to assume that unmanned systems are very important and the top priority, but in the eyes of key military leaders, other areas may require a larger share of the funding based on the current threat.

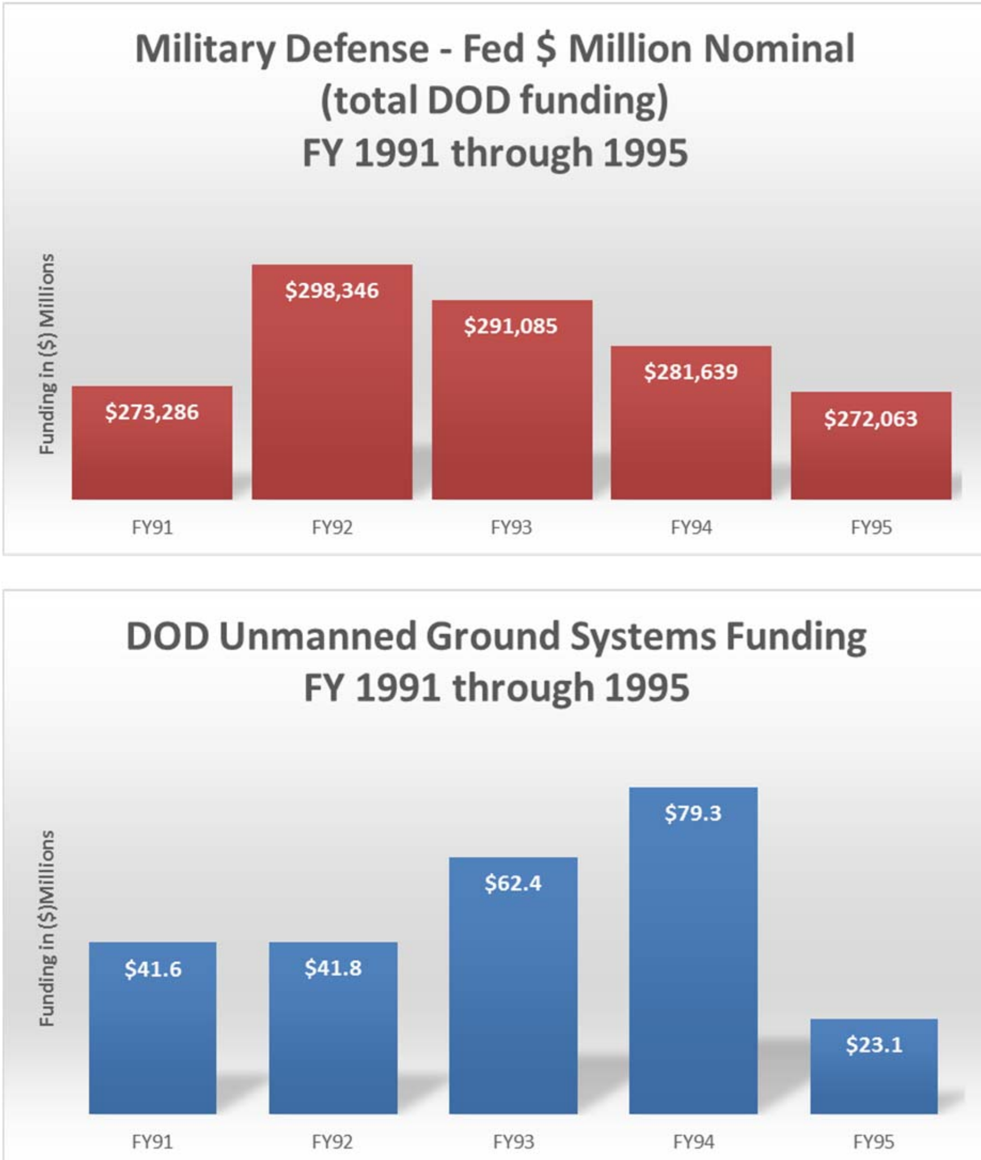


Figure 63. DOD and UGV Funding Comparison 1991–1995 (after DOD, 1991, 1992, 1993, 1994, 1995; usgovernmentspending.com, n.d.)

It is evident in the first five years of the UGV program that the schedule for each program slipped further into the future than was originally planned. The challenge for program managers is the program budget can change from year to year and a reduction in funding to a program could result in an adjustment to the schedule, further into the future when funding is cut. The funding charts depict the unpredictable nature of funding each year, with the exception of the TUGV program, which increases funding each year, though its schedule slips further into the future. This leads into the final point to consider:

unmanned technology is new and complex and far from a mature technology. Schedules can easily slip when technology is not developed at the rate that was expected. Technology also does not develop at the expected rate when funding for R&D is cut. This is a concept that can affect any DOD program, especially when the technology is cutting edge and immature.

B. 1996 MASTER PLAN THROUGH 2000 MASTER PLAN

In Section B, the research identifies each UGV program mentioned in the master plans from 1996 to 2000, and conducts a comparative analysis of the schedule and funding of each program. The purpose of the research is to identify adjustments to the overall schedule and funding while examining program growth in terms of new systems and UGV program funding. The section concludes with an analysis of schedule and funding from 1996 to 2000 on programs that continued through the years observed.

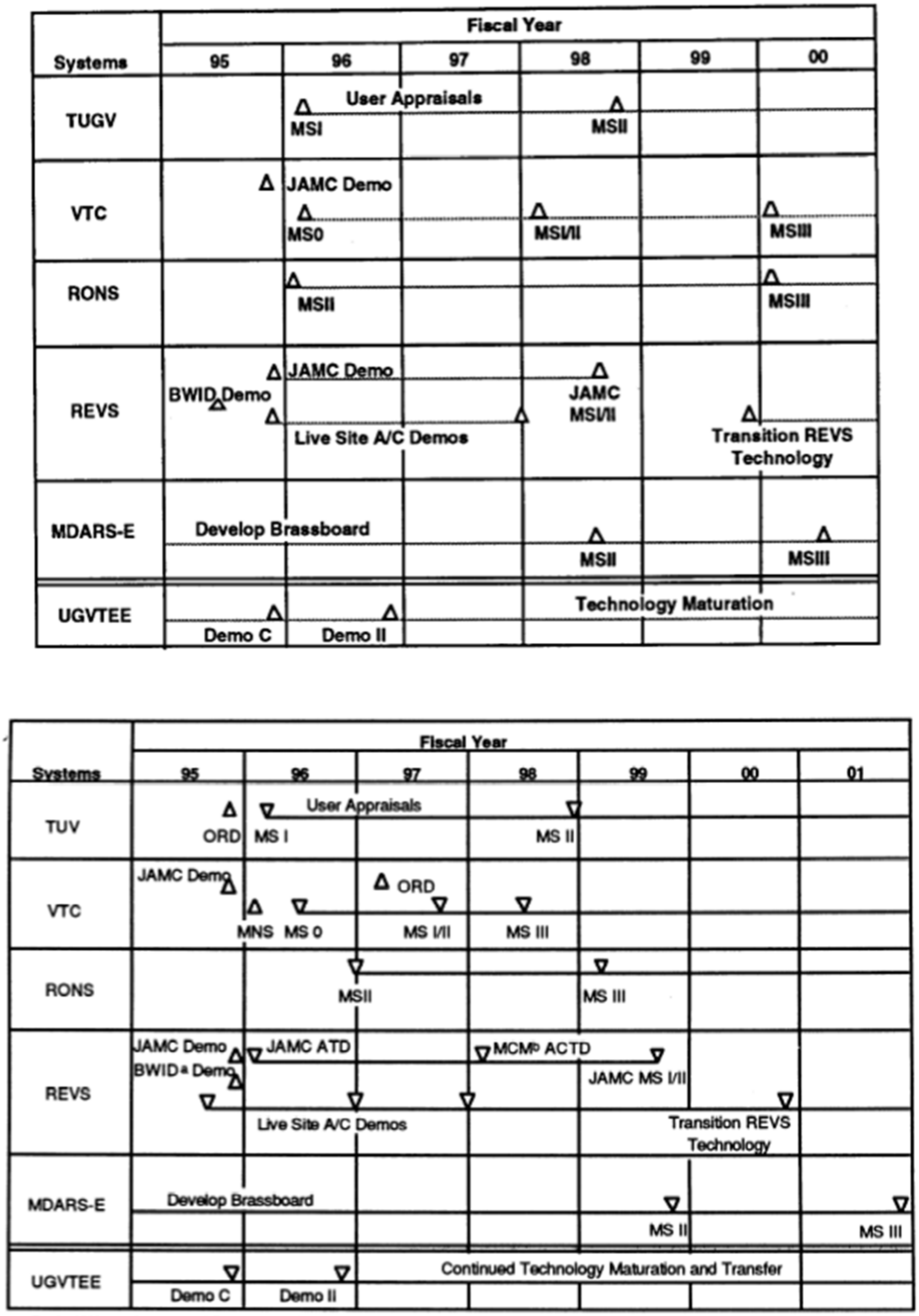
1. 1996 Unmanned Ground Vehicle Master Plan

From 1995 to 1996 no new programs were added, but the DEMO II program was concluded with the results explained in greater detail later in this section. At this time, U.S. forces were also deployed to Bosnia and the need for unmanned mine clearance became a requirement that the UGV program was able to fulfill. The VTC program quickly elevated in status as this capability proved its effectiveness in real world situations. The TUGV program dropped the letter *G* from its name, and it is now referred to as the tactical unmanned vehicle (TUV) in this master plan. The requirements that led to the solution for that year is shown in Table 13.

Table 13. Requirements Articulation 1996 UGV Master Plan

1996
Requirement
Breaching
Countermine Operations
Develop & Field family of UGVS for range of military applications IAW user requirements
Environmental Cleanup
Explosive Ordnance Disposal
Firefighting, handling & loading of aircraft munitions, multiple UXO during clearing operations
Logistics
Military Operations in Urban Terrain (MOUT)
Minefield Detection & Neutralization
NBC Detection and Laser Designation
Obstacle Detection
Physical Security
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
Remote Mine Clearance
TUGV - Supporting the Infantry
UXO Emerged
Threat/Conflict
Lessons learned in Bosnia
UGV Solution
Tactical Unmanned Ground Vehicle (TUGV) renamed Tactical Unmanned Vehicle (TUV)
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
NBC Detection and Laser Designation
Robitic Evacuation Vehicle(Rev) (renamed from RRR)
Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas)
Remote Ordnance Neutralization Device (ROND)/Remote Ordnance Neutralization System(RONS)(Initiated 1990)
Explosive Ordnance Disposal
Mobile Detection Assessment Response System - Interior/Exterior (MDARS-I/E) (Initiated 1992)
Reduce manpower by patrolling exterior of buildings and compounds in day, night, hot, cold, wet & dry conditions
Added security inside military facilities such as large warehouses and depots
Vehicle Teleoperation Capability (VTC) (Initiated 1993) (renamed from EVTC)
Remote Mine Clearance
Breaching
Environmental Cleanup
Joint Architecture for Unmanned Ground Systems (JAUGS) (Initiated 1995)
Develop common hardware/software open achitecture to ensure intraoperability (vehicle to vehicle)
Interoperability (data communications in command, control, communications, computers & intel (C4I) result in cost savings
Unmanned Ground Vehicle Technology Enhancement and Exploitation (UGVTEE)
**Unmanned mine clearance became requirement from lessons learned in Bosnia (focus on TUV program)*

Even though the UGV program did not add any new projects, there were some notable changes to the overall program schedule. Figure 64 compares the 1995 UGV master plan schedule to the 1996 schedule. The TUV schedule had minimal changes, with only Milestone II shifting about one quarter further into the future. All other UGV programs experienced significant schedule shifts in the past year. The most noteworthy shift is the VTC program moving several milestones ahead of the previously planned schedules. This is in response to the conflict in Bosnia and demand for unmanned mine clearance support. The RONS, REVS, and MDARS-I/E programs all experienced shifts of milestones further into the future than what was planned the year prior.



[a] Buried Waste Integrated Demonstration

[b] Mine Countermeasures

Figure 64. 1995 UGV Program Master Schedule Compared to the 1996 UGV Program Master Schedule (from DOD, 1995, 1996)

The change in funding from 1995 to 1996 for all key programs tracked and funded by OSD and the services is shown in Table 14. The TUV program funding is up for the current year, FY96, but then it declines from FY97 to FY01, deviating from what was previously planned. This is likely tied to the increased funding for the VTC program that is gaining momentum based on the situation in Bosnia. VTC funding almost doubles each year from FY96 to FY01. OSD funding for this program was set to expire in FY98 according to the 1995 master plan, but this has since been extended to FY02. There are minor changes to the REVS and RONS funding compared to what was planned the year prior, and this information is covered in greater detail in each program's respective section.

Table 14. Funding for ASD Programs in 1995 Compared to Funding for ASD Programs in 1996 ($M; from DOD, 1995, 1996)

ASD Program	FY95	FY96	FY97	FY98	FY99	FY00	FY01
TUGV	10.0	7.2	12.8	17.5[c,d]	18.2	19.0	19.8
VTC	2.0	2.5	3.0	0	0	0	0
REVS	1.4[a]	2.5	3.5	3.0	3.0	3.0	3.0
RONS	0.4[b]	0.4[c]	0.4	0	0	0	0
Totals	13.8	12.6	19.7	20.5	21.2	22.0	22.8

a The Services and DoE are funding $6.4M in FY95 and $5.5M in FY96.
b The Navy is funding 550K to complete advanced system development.
c Transitions to EMD in the indicated year. The Services have programmed funds.
d The RSTA version of TUGV expects to enter EMD in FY98. Funds shown in FY98-FY01 are for other potential projects in the TUGV family.

ASD Program	FY96	FY97	FY98	FY99	FY00	FY01	FY02
TUV	8.40	8.70	10.30	10.70	11.10	11.00	11.60
VTC	4.00	5.40	4.80	4.80	5.00	5.00	5.00
REVS	2.50	3.50	3.00	3.50	3.50	4.00	4.00
RONS	0.40	0.40	0.40	0.00	0.00	0.00	0.00
Totals	15.30	18.00	18.50	19.00	19.60	20.00	20.60

a. TUGV/TUV from 1995 to 1996

In years prior, the TUV program was composed of multiple UGV systems. This group of systems has been reduced, and the primary focus lies within the surveillance and assessment robot for GI enhancement (SARGE), the tactical test bed (TTB), HMMWVs, and the Gecko. In the past year, five SARGE vehicles were delivered to 3rd Infantry Division at Fort Benning, GA for user familiarization and evaluation. The Gecko demonstrated its ability to conduct remote reconnaissance at a military operations in urban terrain (MOUT) village (DOD, 1996). When the systems were delivered, key personnel were trained on the functionality of the systems. Key personnel then recommended possible implementation methods of the systems within the force. The systems were then utilized by Soldiers conducting training operations with feedback utilized for system improvements and requirements refinement.

The 1996 master plan states to expect requirements from the armor and artillery communities in the near future (DOD, 1996). At face value, it appears that the role of the TUV expanded beyond the infantry community to the armor and artillery branches as a system designated for infantry RSTA. However, in its current state, it seems difficult to determine if the TUV is received well by the infantry community, and the technology may see a shift to other areas of the Army.

Figure 65 depicts the 1996 TUV schedule planned through FY99. On January 26, 1996, the TUV achieved Milestone I. Milestone II has shifted about one quarter further into the future, but EMD has moved almost two years into the future from what was planned last year.

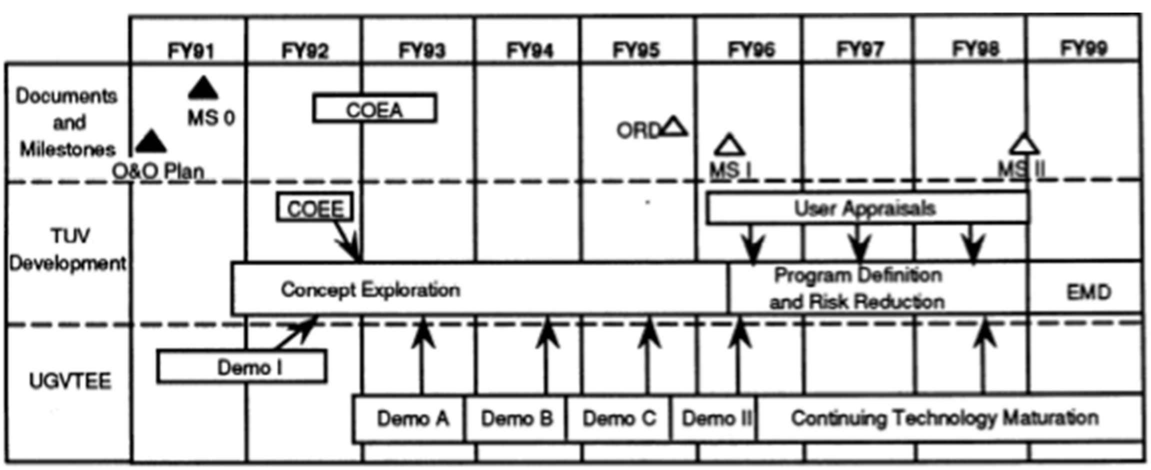


Figure 65. 1996 TUV Program Schedule (from DOD, 1996)

As mentioned earlier, the planned funding of the TUV program has decreased for all years except for the current year. It appears to be a common trend that TUV funding for the current year seems higher than what was planned the year prior. The TUV funding may see a decrease due to the increased need for the VTC in support of operations in Bosnia, or because the program is not meeting the needs of the users in the infantry community. This may also reflect a function of operating in a period of time when the DOD budget shows reduction and unpredictability. UGV program funding compared to DOD funding is presented in this paper to analyze funding trends of the program against the big picture funding of the military at large.

b. RONS from 1994 to 1996

In the past year, the RONS program completed developmental testing of the program's advanced development model (ADM). The RONS program schedule changes from 1994 to 1996 is shown in Figure 66. The Milestone II decision shifts about nine months into the future from what was planned the year prior. In preparation of Milestone II, a study conducted to determine further development of the system's ADM will cease with upgrades focused on the system's remote control transporter currently fielded with the units (DOD, 1996). While Milestone II was delayed, Milestone III and the Operational Evaluation were shifted to occur about one year earlier from what was planned in 1995. DT&E is also predicted to occur earlier than last year's plan. These shifts in the RONS program schedule are interesting because this is essentially what the plan looked like in the 1994 master plan.

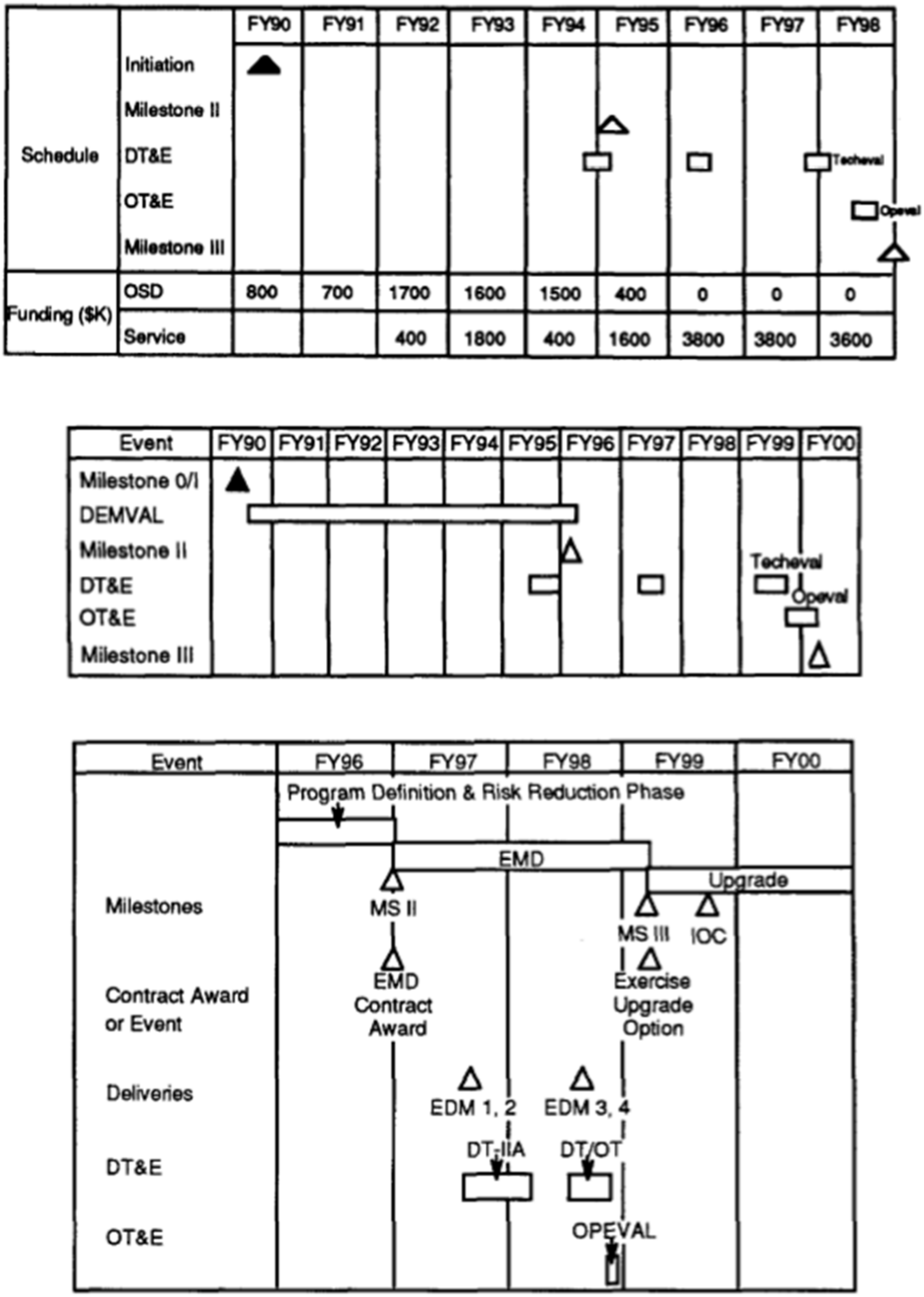


Figure 66. Changes to RONS Program Schedule from 1994 to 1996 (from DOD, 1994, 1995, 1996)

c. REVS from 1995 to 1996

Since the last report, the REVS program has made some notable progress. Obstacle avoidance technology that was developed in the DEMO II program was completed and currently incorporated into the REVS program. Also, an automated ordnance excavator (AOE) used in a live demonstration successfully found buried UXO, dug up the UXO, and removed the UXO from active military ranges (DOD, 1996). As mentioned in the 1995 section, the REVS is a technology that is sought after by industry since many contractors play a significant role in the removal of UXO from locations previously used as ranges by the U.S. military. Based on this demonstration, the first stage of technology transfer to industry appears ready to occur.

Figure 67 is the 1996 REVS program schedule. In the REVS schedule presented in 1995, Milestone I/II were easy to distinguish on the schedule, but is not very prominent on the 1996 schedule. It has either shifted so far into the future, beyond FY00, or it is depicted as the MCM ACTD triangle on this schedule and has shifted about one year into the future from what was previously planned. The live site demonstrations have been extended an additional two years on the 1996 schedule and the REVS test, analyze and fix portion has been extended by one year. Lastly, the transition of REVS technology has slipped one year further into the future in one year's time.

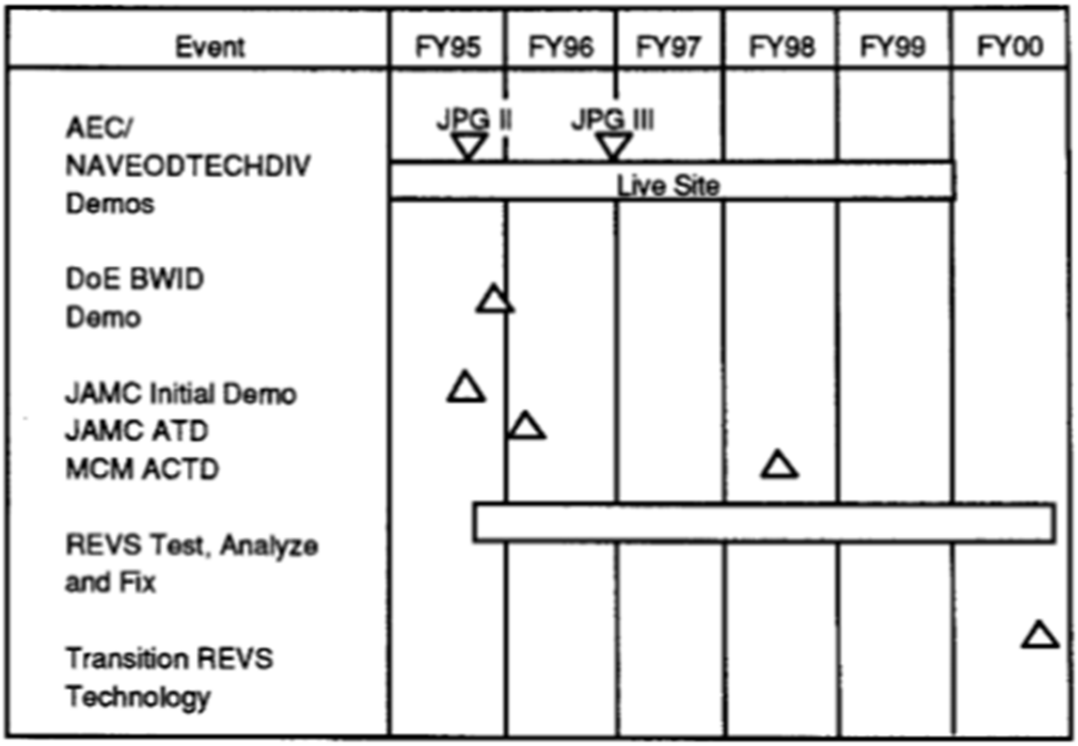


Figure 67. 1996 REVS Program Schedule (from DOD, 1996)

d. VTC from 1995 to 1996

Of all UGV programs, the VTC program seems to have made the largest impact in the past year due to the operations in Bosnia. First, the program achieved Milestone 0 in July 1996. Second, variants of the VTC system developed by the UGV/S JPO and the Office of Science and Technology for Special Operations Forces were fitted to M-60 turretless tanks, and successfully used in countermine operations in Bosnia. Lastly, a VTC variant for the HMMWV was built, demonstrated, and delivered to support the Program Manager of Mine, Countermine, and Demolitions (MCD; DOD, 1996). This appears as a huge success story for UGVs. The VTC also successfully accomplished its mission in Bosnia, as the UGVs detonated several mines during clearance operations. During these missions, the operator was located in a separate vehicle unexposed to danger when the mines detonated. The biggest challenge remains the limited number of VTCs available to units deployed in Bosnia.

The VTC program schedule in 1996 compared to the schedule in 1995 is shown in Figure 68. The key take away is that the Milestone I/II decision and EMD phase has moved almost one year ahead of where it was planned in 1995. The Milestone III decision has moved ahead by about two years. The use of this system in Bosnia appears to serve as the driving force behind the push to complete the schedule faster than planned and could also explain more funding allocation planned for the VTC program.

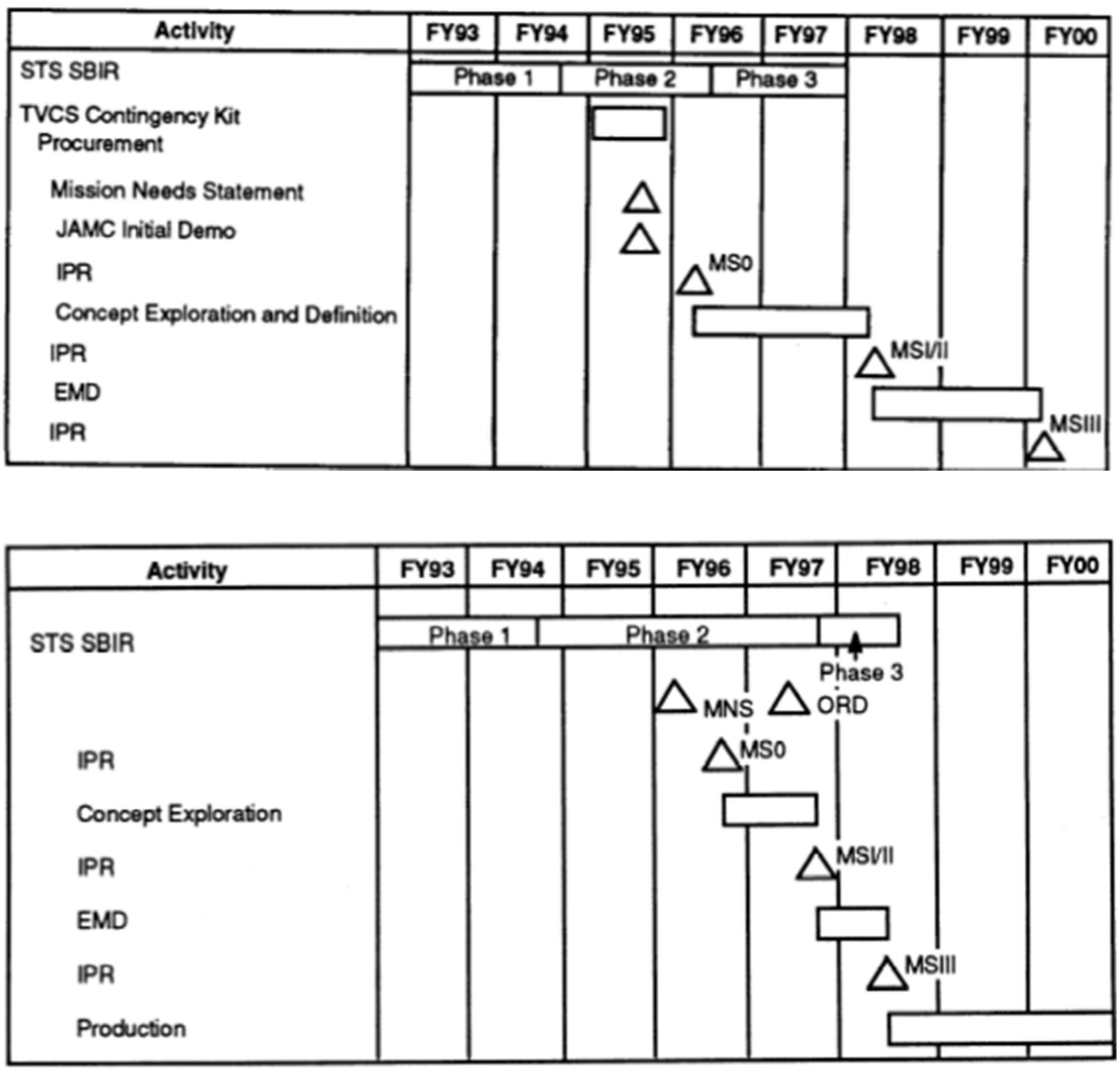


Figure 68. 1995 VTC Program Schedule Compared to 1996 VTC Program Schedule (from DOD, 1995, 1996)

e. DEMO II from 1995 to 1996

DEMO C and DEMO II successfully concluded as planned in June 1996. This program successfully demonstrated various technology advancements that support the evolutionary development of UGVs and the technology transfer envisioned at the beginning of the program.

> DEMO II demonstrated the potential operational value of an integrated set of technologies for a UGV scout that increases the survivability of forces engaged in high risk missions, provides commanders with new tactical options, and allows effective integration into the manned force structure. (DOD, 1996, p. 30)

One of the major goals following this program is the transference of this technology to users in the military and civil sector for various uses. The DEMO I and II programs were the biggest contributor to the technology development seen throughout the UGV program and this aggressive schedule forced innovation beyond current availability.

While highly autonomous operations have not reached achievement to date and it is difficult to say when this may occur, enormous strides in supervised autonomous operations have resulted. The DEMO II program made a key decision to involve Soldiers in a live training demonstration, which was key to stimulating the user for further operational uses and to refine requirements. Several developments from this program have been transferred to the various UGV programs mentioned in the previous sections and this technology continues to mature. The document refers to the technology development and transfer as the unmanned ground vehicle technology enhancement and exploitation (UGVTEE) program. This is the continuation of the DEMO I and II programs and is the next logical step for continued technology development. "The UGVTEE program for the next five years entails three integrated thrusts: concerted technology development and transfer, next-generation unmanned vehicle platform integration and demonstration, and near-term JPO technology insertion" (DOD, 1996, p. 35). The aggressive DEMO II program served as a forcing function that delivered results. It made sense for another developmental program with an aggressive time line to emerge with hopes of achieving further technology gains.

f. MDARS-I/E from 1995 to 1996

In the past year, the MDARS-E prototype vehicle was developed and successfully completed its demonstration. Additionally, this program completed what is called a concept formulation package, which consists of tradeoff determination (TOD), tradeoff analysis (TOA), best technical approach (BTA), and cost and operation effectiveness analysis (COEA; DOD, 1996). Little is known about the funding of this program, and the amount of units procured has not appeared in the last few master plans.

The 1996 MDARS-I schedule compared to what was presented in 1995 is shown in Figure 69. The schedule seems to slip further into the future each year that a new schedule is presented. In the past year, Milestones II and III have each shifted about six months to one year further into the future. This effects other portions of the schedule as well as the contract award, EMD, and production are also moved further into the future by no less than six months.

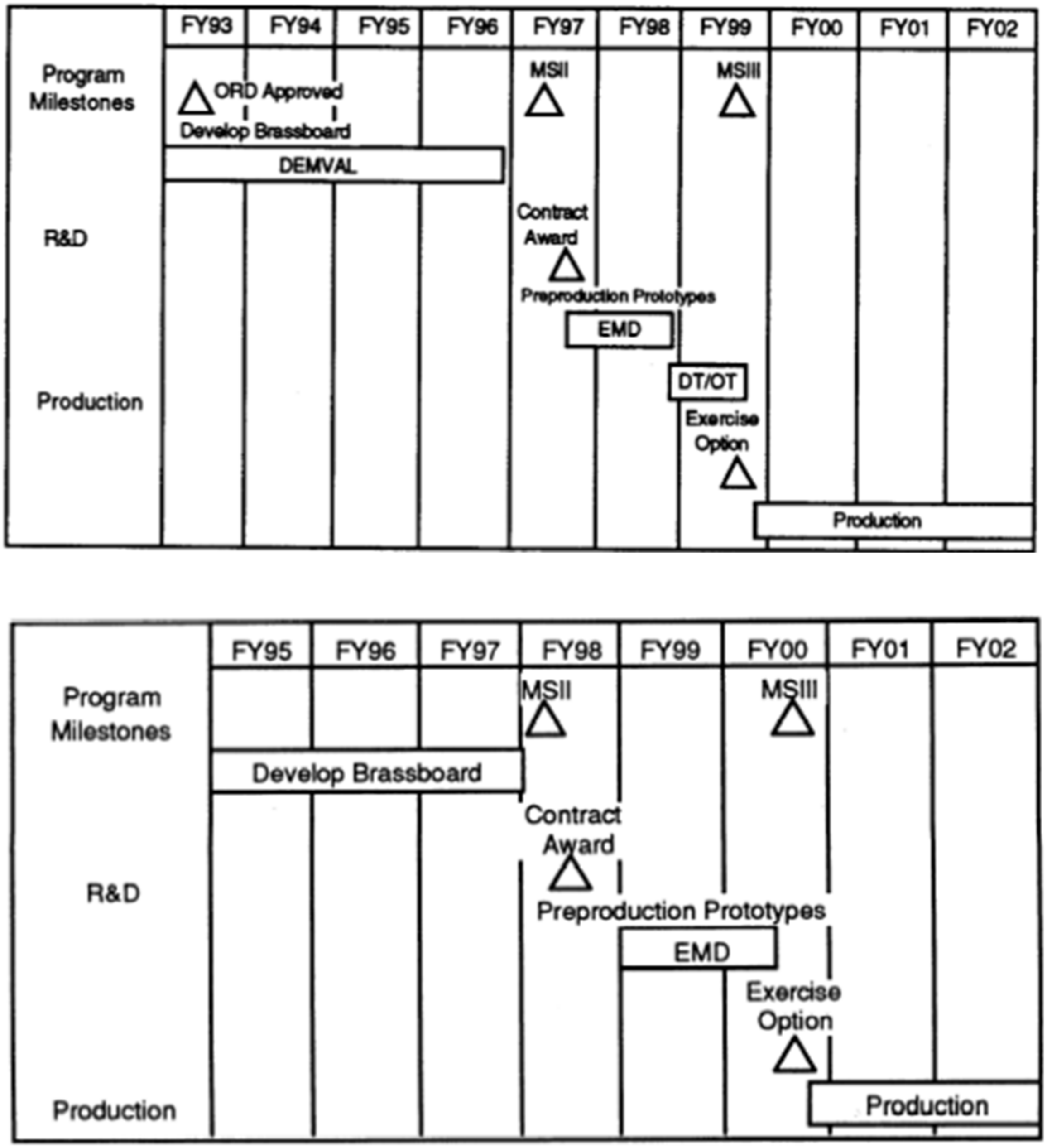


Figure 69. MDARS-I Program Schedule from 1995 Compared to MDARS-I Program Schedule from 1996 (from DOD, 1995, 1996)

The situation is almost identical for the MDARS-E schedule which is presented in Figure 70. Milestones II, III, contract award, EMD, and production have all shifted further into the future for this program compared to what was presented in 1995.

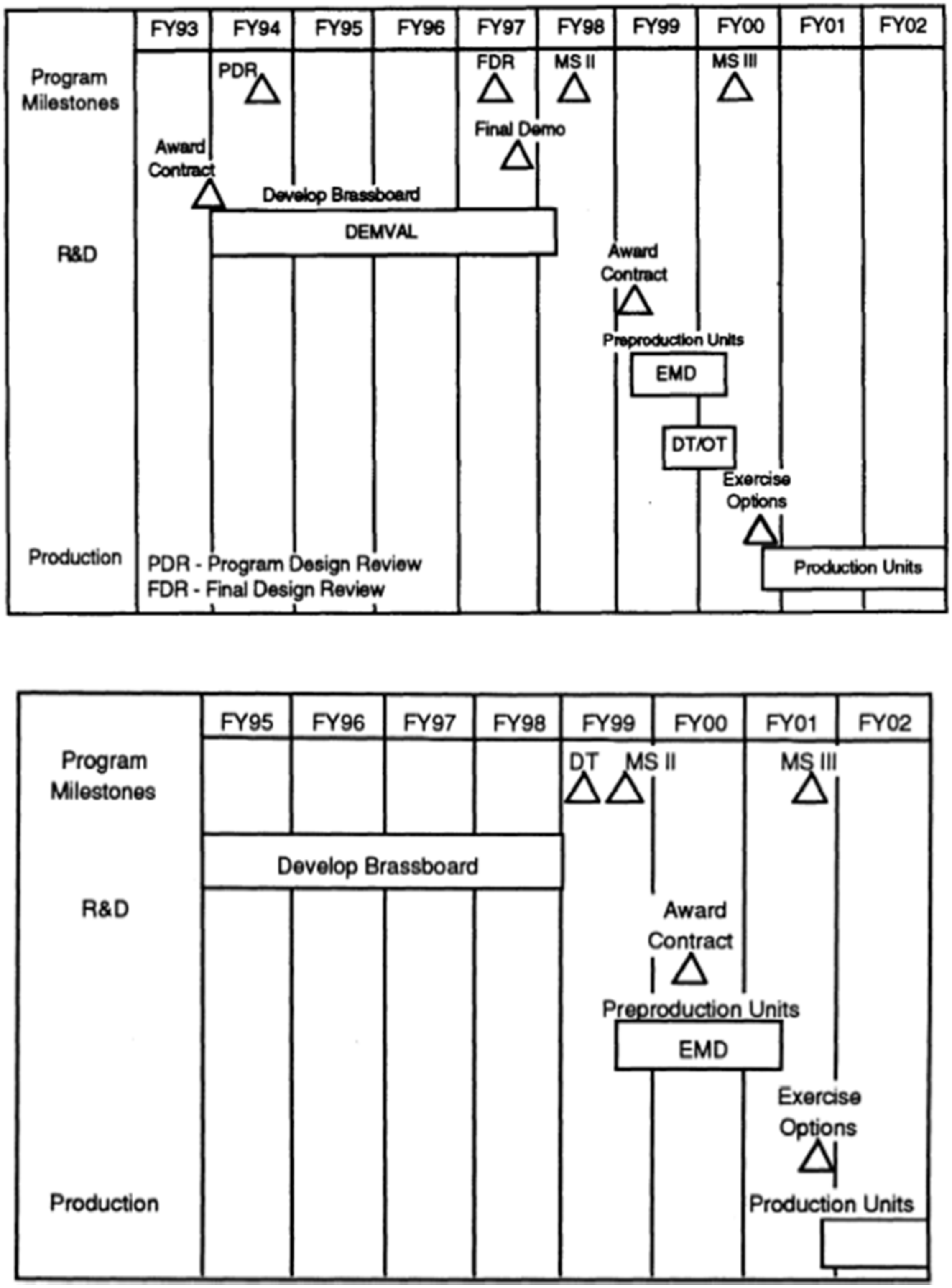


Figure 70. 1995 MDARS-E Program Schedule Compared to 1996 MDARS-E Program Schedule (from DOD, 1995, 1996)

Even though the MDARS-I/E schedule shows signs of slipping into the future, the value of such a system receives attention by not only the military, but also the government and the civil sector. There are valuable uses for this technology outside of the military that could lead to a larger research and development effort, nationally and globally.

> The MDARS program has major dual-use potential both for other Government agencies and for commercial use. The DOE has expressed an interest in both the MDARS-I and MSARS-E. J.C. Penney and Glaxo Pharmaceuticals are currently implementing an inventory control capability using MDARS-I. (DOD, 1996, p. 29)

This is an interesting development particularly from the standpoint of R&D. As more corporations see the value of unmanned systems, the R&D funding pool grows and creates opportunities for advanced technology maturation or breakthroughs. The more that UGVs are accepted and implemented, the more attention the development of technology receives and this leads to a virtuous development cycle.

g. JAUGS from 1995 to 1996

In last year's master plan, a one-year joint architecture for unmanned ground systems (JAUGS) schedule was presented. Although an updated and refined version was expected in this year's plan, the JAUGS program schedule does not appear in this master plan and is only briefly discussed. The plan states that a working group developed the initial requirements for the JAUGS program and an additional group worked with industry partners to gain feedback and recommendations related to JAUGS architecture and requirements (DOD, 1996). There is not a formidable plan presented for the future of JAUGS, so JAUGS significance seems difficult to assess at this time.

h. Conclusion

Prior to this master plan, there had not been an opportunity to utilize UGVs in a combat situation. The conflict in Bosnia served as the first opportunity for the UGV program to prove its worth in real-world situations. This is likely what reshaped the funding of the TUV program, which was the main effort of the UGV program. The VTC schedule also changed to achieve the program's milestones at a faster pace and further monitoring of funding and schedules conducted indicated how program priorities can change during times of conflict compared to what was planned prior to the conflict.

The conclusion of DEMO II marks the end of a well-structured and aggressive technology development program with measurable and significant advancements since DEMO I. Programs of a similar nature are the key to the UGV program's future success.

2. 2000 Joint Robotics Master Plan

During the data collection portion of this project, no master plans from 1997, 1998, and 1999 could be found. When the FY00 master plan was found, the name of the plan was changed from unmanned ground vehicle master plan to joint robotics program (JRP) master plan. The requirements that led to the solution for that year is shown in Table 15.

Table 15. Requirements Articulation 2000 Joint Robotics Master Plan

2000
Requirement
Breaching
Countermine Operations
Develop & Field family of UGVS for range of military applications IAW user requirements
Environmental Cleanup
Explosive Ordnance Disposal
Firefighting, handling & loading of aircraft munitions, multiple UXO during clearing operations
Logistics
Military Operations in Urban Terrain (MOUT)
Minefield Detection & Neutralization
NBC Detection and Laser Designation
Obstacle Detection
Physical Security
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
Remote Mine Clearance
Small, lightweight, man-portable UGV to be used for Recon urban environment & other terrain (Infantry/Armor)
TUGV - Supporting the Infantry
UXO
Threat/Conflict
Unmanned mine clearance, lessons learned in Bosnia and Kosovo (peacekeeping mission)
UGV Solution
Tactical Unmanned Vehicle (TUV) renamed Family of Tactical Unmanned Vehicles (FTUV) Reconnaissance, Surveillance, and Target Acquisition (RSTA) NBC Detection and Laser Designation **Robitic Evacuation Vehicle(Rev) renamed Robotic Ordnance Clearing System (ROCS)** Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas) - All-Purpose Robotic Transport System (ARTS) - clear paths on ranges or minefields (ARTS-FP)- clearance of large UXO or potential IEDs - Active Range Ordnance Mapping System (AROMS) - Automated Ordnance Excavator (AOE) (1996) **Remote Ordnance Neutralization System(RONS)(Initiated 1990)(renamed from Remote Ordnance Neutralization Device (ROND)** Explosive Ordnance Disposal **Basic UXO Gathering System (BUGS) (initiated 2000) (RONS+FUTV+REVS)** Part of the RONS program salvaged and merged with parts from the REVS and TUV to create BUGS man-portable, EOD support UGV. **Mobile Detection Assessment Response System - Interior/Exterior (MDARS-I/E) (Initiated 1992)** Reduce manpower by patrolling exterior of buildings and compounds in day, night, hot, cold, wet & dry conditions Added security inside military facilities such as large warehouses and depots **Vehicle Teleoperation Capability (VTC) (Initiated 1993) renamed Vehicle Teleoperation (VT) Program** Remote Mine Clearance Breaching Environmental Cleanup **Joint Architecture for Unmanned Ground Systems (JAUGS) (Initiated 1995)** Develop common hardware/software open achitecture to ensure intraoperability (vehicle to vehicle) Interoperability (data communications in command, control, communications, computers & intel (C4I) result in cost savings **Robotic Combat Support System (RCSS) (initiated 2000) (REVS + VT)** **Unmanned Ground Vehicle Technology Enhancement and Exploitation (UGVTEE)** **Small robots being tested and experimented to determine usefullness to the warfighter. Concept mixed parts of RONS and appears to be beginning of Packbot and Talon Robitic systems* ***Groups of UGVs by class & size is reintroduced: very small (bug size) platforms, man-portable, medium, and full size robotic vehicles*

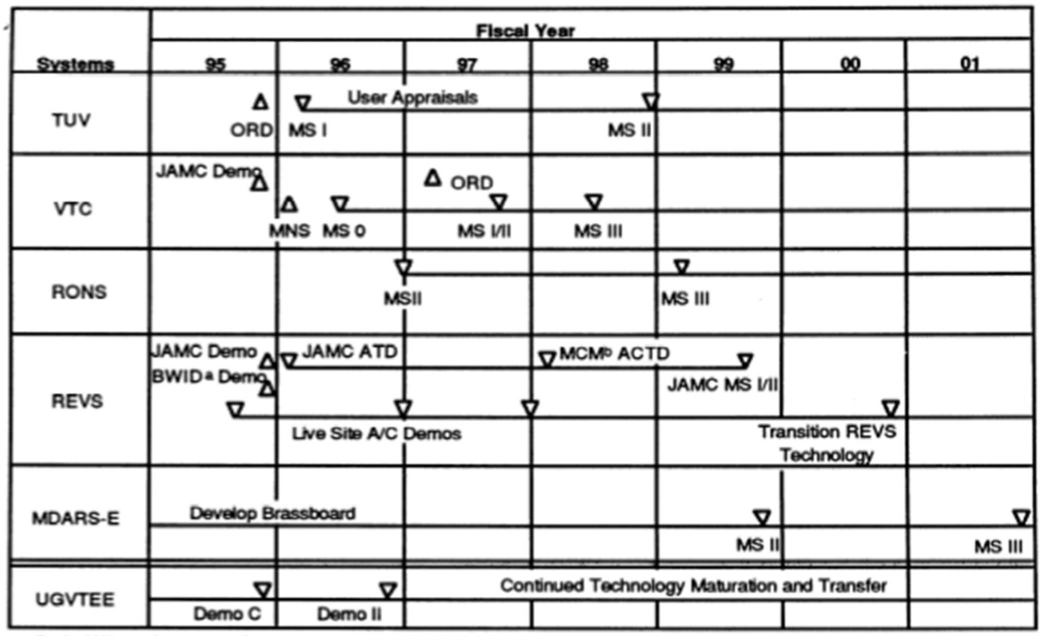
In just a few short years, many significant changes to the overall program occurred and deserve greater attention in this section. Some of the most notable changes include the naming convention of the system programs. The programs shown in Figure 71 display how the names have changed and evolved over the past three years. The corresponding program in 2000 is directly across from its predecessor in 1996. New programs are listed in Figure 71. The TUV program is now the family of tactical unmanned vehicles (FTUV). Parts of the RONS program were salvaged and merged with parts from the REVS and TUV programs to create the basic UXO gathering system (BUGS) program. The REVS program still exists as it was and is now called robotic ordnance clearing system (ROCS). The VTC program is now the vehicle Teleoperation (VT) program. There is also the emergence of a new program called robotic combat support system (RCSS), which appears to have evolved from REVS and VTC technology.

1996 Program Name	2000 Program Name
Tactical Unmanned Ground Vehcile (TUGV)	Family of Tactical Unmanned Vehicles (FTUV)
Remote Ordnance Neutralization System (RONS)	Remote Ordnance Neutralization System (RONS)
Robotic Excavation Vehicle System (REVS)	Robotic Ordnance Clearing System (ROCS)
Vehicle Teleoperation Capability (VTC)	Vehicle Teleoperation (VT)
DEMO II	DEMO III
Mobile Detection Assessment Response System-Interior/Exterior (MDARS-I/E)	Mobile Detection Assessment Response System-Interior/Exterior (MDARS-I/E)
Joint Architecture for Unmanned Ground Systems (JAUGS)	Joint Architecture for Unmanned Ground Systems (JAUGS)
	Basic UXO Gathering System (BUGS)
	Robotic Combat Support System (RCSS)

Figure 71. Program Names from 1996 to 2000

The MDARS-I/E program is the only program that has not changed its name since program inception. Under the UGVTEE program, a new technology development program was created and it is called DEMO III. Ideally, this program delivers results that are as impactful as the DEMO II program.

The change to the master schedule for all programs from 1996 to 2000 is shown in Figure 72. Generally, all schedules have slipped further into the future compared to what was planned in 1996. The MDARS-I is now added to the schedule for the first time to accompany the MDARS-E program. Most notable is the fact that the FTUV does not appear on the schedule, with no explanation as to why not.



a Buried Waste Integrated Demonstration

b Mine Countermeasures

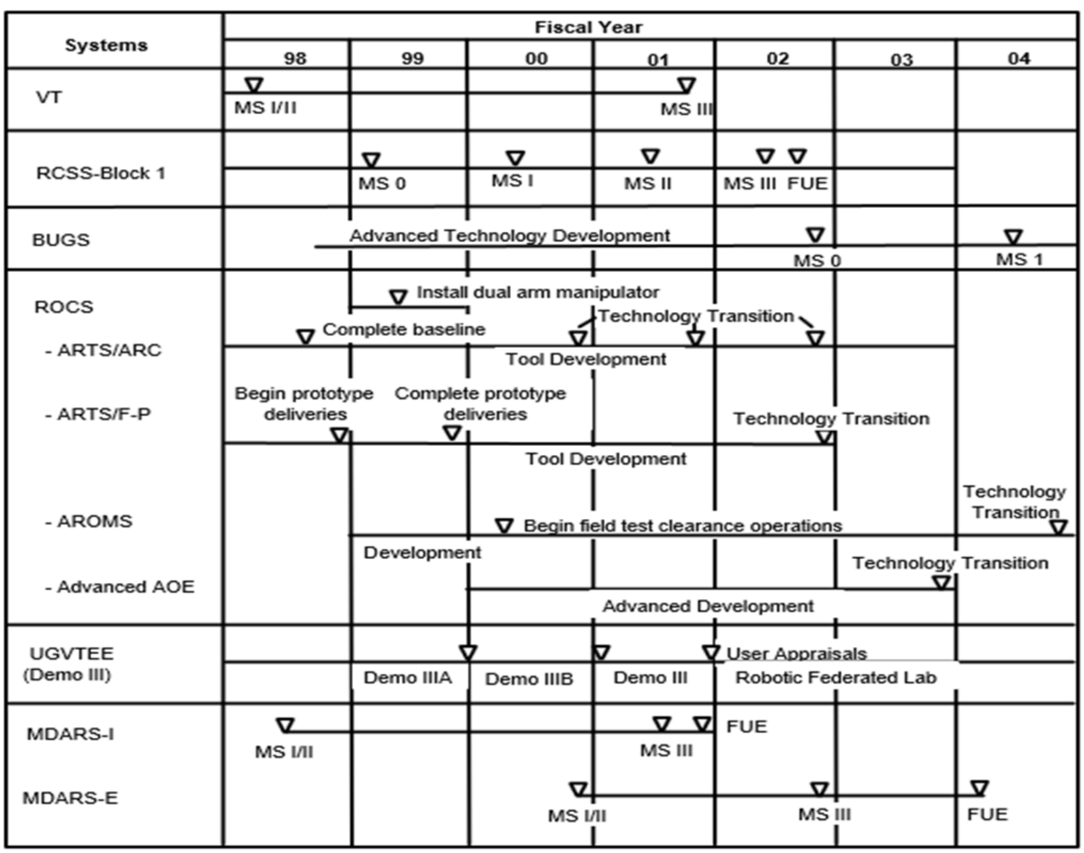


Figure 72. 1996 UGV Master Schedule Compared to 2000 UGV Master Schedule (from DOD, 1996, 2000)

Table 16 compares the program funding changes from 1996 to 2000. For the most part, all programs have increased funding, with the FTUV receiving less funding than originally planned. MDARS funding is also visible for the first time in a master plan.

Table 16. 1996 UGV Program Funding Compared to 2000 UGV Program Funding (from DOD, 1996, 2000)

ASD Program	FY96	FY97	FY98	FY99	FY00	FY01	FY02
TUV	8.40	8.70	10.30	10.70	11.10	11.00	11.60
VTC	4.00	5.40	4.80	4.80	5.00	5.00	5.00
REVS	2.50	3.50	3.00	3.50	3.50	4.00	4.00
RONS	0.40	0.40	0.40	0.00	0.00	0.00	0.00
Totals	15.30	18.00	18.50	19.00	19.60	20.00	20.60

Project	FY99	FY00	FY01	FY02	FY03	FY 04	FY05
Engineer UGVs (VT, RCSS)	11.6	13.3	9.1	8.2	8.0	5.0	5.0
FTUV	2.0[a]	3.0	5.0	8.0	8.0	11.4	11.8
Range Clearance/Force Protection UGVs (ROCS)	3.6	3.6[b]	4.0	4.1	4.5	4.5	4.5
EOD UGVs (BUGS)	0.7	0.7	0.7[c]	1.0	2.0	2.0	2.0
Physical Security (MDARS)	3.1[d]	1.7	2.5	3.0	0.0	0.0	0.0
UGVTEE (Demo III)	9.2[e]	10.1	0.0	0.0	0.0	0.0	0.0

a. TUV/FTUV from 1996 to 2000

In previous master plans, the family of tactical unmanned vehicles (FTUV) received the main focus of unmanned ground programs, but this appears to have shifted in the latest master plan. Information on the FTUV appears limited and shows no sign of a schedule for this program anywhere in the plan. The overall funding to this program also shows drastic cuts, down to a mere $2 million in FY99. In 1996, over $10 million of funding was allocated for this program. Basically, all funding planned in 1996 is significantly lower for FTUV in 2000.

One interesting point raised in the 2000 JRP master plan identifies the consideration of a requirement by the infantry and armor schools, for a small, lightweight, man-portable UGV used for reconnaissance missions in urban environments and in other terrain (DOD, 2000). These small robots are being tested and experimented on to determine their usefulness to the warfighter. This concept mixed with parts of the RONS program appears to reflect the beginning of how the PackBot and Talon robotic systems became the systems known today.

Under the FTUV program, the SARGE system remains the vehicle of choice. The master plan describes SARGE as a platform that is useful for testing new ideas and configurations while serving as the system that allows for modularity in support of future improvements (DOD, 2000). This system has been the primary system for many years and does support the evolutionary strategy associated with the overall UGV program strategy.

The last point worth mentioning with the FTUV program is that the program is considering a change to the structure of the FTUV program. This idea to group UGVs by class or size has been seen before as the master plan describes "a family of TUVs that may include very small (bug size) platforms, man-portable versions, and medium to full size (e.g., M-1 tanks) robotic vehicles" (DOD, 2000, p. 23). A similar class convention has been done before and was abandoned by the program office. There is value to having distinct classes and sizes to the UGVs, but there is also a point when so many changes can lead to confusion and could possibly be detrimental to a program. A class size by weight to the overall UGV program seems the most appropriate choice to promote consistency or standardization throughout all services.

b. REVS/ROCS from 1996 to 2000

In the 2000 master plan, each program under ROCS is clearly delineated and explained. It is now understood that ROCS is a significant program with three separate programs under this listing. "The robotic ordnance clearing system (ROCS) program is currently composed of the following developments: the all-purpose robotic transport system (ARTS), the active range ordnance mapping system (AROMS), and the automated ordnance excavator (AOE)" (DOD, 2000, p. 28). Overall, the systems in the program remain quite similar but signs of advancement do exist. The AOE served as one of the featured systems in the 1996 master plan. As the capabilities that make up the AROMS were in exploration in the earlier master plan, it can now be seen how they have come to fruition in a specific system.

The ARTS while not a formally named system in 1996 yielded developed named programs. The ARTS is broken up into two different systems with capabilities discussed in the past. The ARTS/active range clearance (ARC) model is designed to clear paths on ranges or mine fields so that EOD personnel can safely travel after the UGV clears. The ARTS/force protection (F-P) is for more focused clearance of large UXO or potential IEDs. The system can also be remotely operated from up to 5 km away and multiple tools can be affixed to the system to accomplish a variety of tasks. The 2000 master plan states that the ARTS is currently being procured and fielded. Thirteen ARTS/F-P units and Five ATRS/ARC units have been fielded at various locations around the globe (DOD, 2000). This is a sign of the success, demand and usefulness of this program.

The 1996 schedule for the REVS and ROCS (seen in Figure 73) programs were not very informative and did not specify program milestones. The ROCS schedule clearly displays each system and the intended outcomes, but the big picture status of the overall program is difficult to determine. Table 17 compares the funding that was planned for the REVS program in 1996 against what is planned for the ROCS program in 2000. The funding appears to have stayed on track, with very small changes overall from what was planned a few years ago. The schedule depicts accomplishments that align with delivery of final products and the funding appears stable, further supporting this being a well-run program.

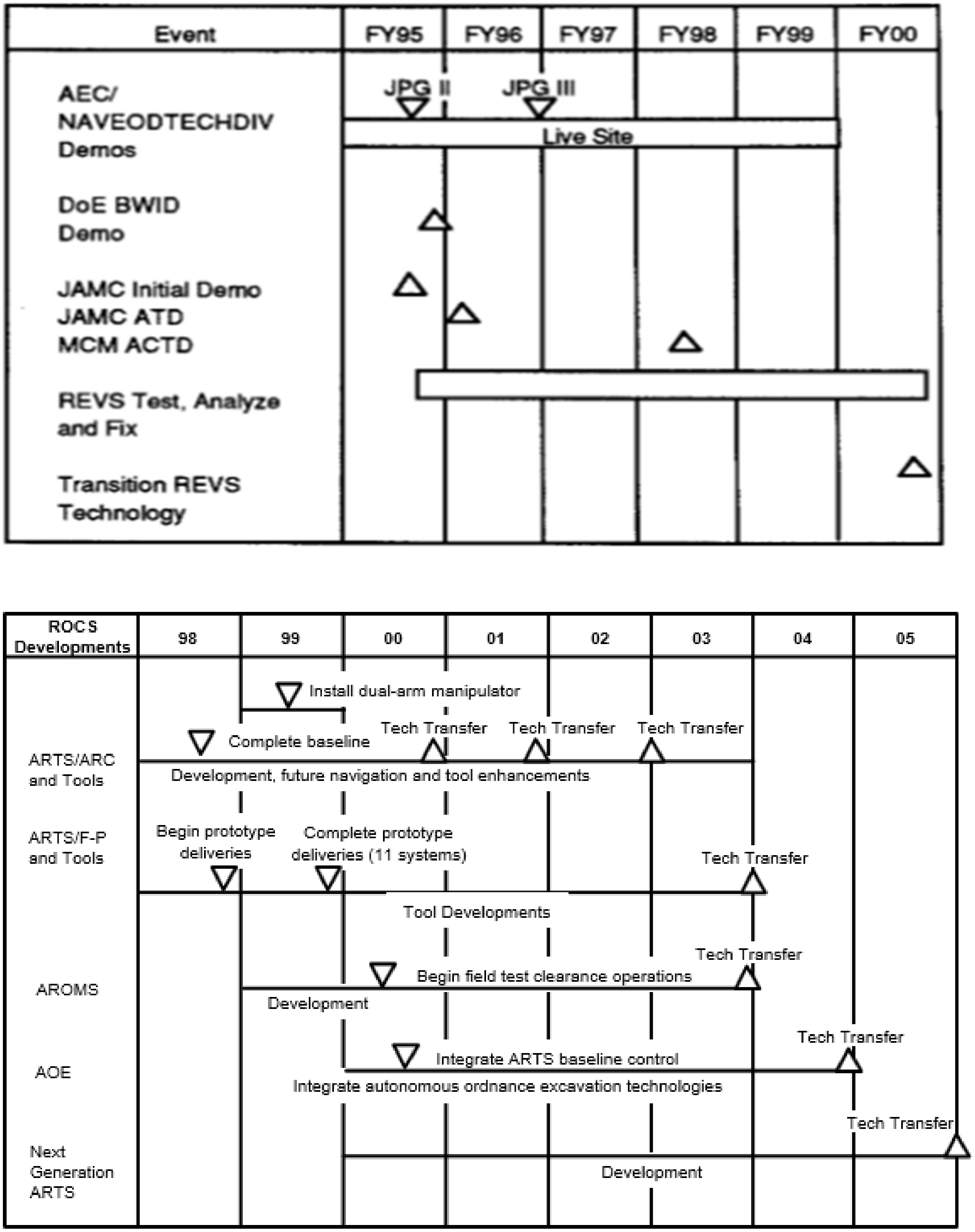


Figure 73. 1996 REVS Schedule Compared to 2000 ROCS Schedule
(from DOD, 1996, 2000)

Table 17. 1996 REVS Funding Compared to 2000 ROCS Funding (from DOD, 1996, 2000)

ASD Program	FY96	FY97	FY98	FY99	FY00	FY01	FY02
TUV	8.40	8.70	10.30	10.70	11.10	11.00	11.60
VTC	4.00	5.40	4.80	4.80	5.00	5.00	5.00
REVS	2.50	3.50	3.00	3.50	3.50	4.00	4.00
RONS	0.40	0.40	0.40	0.00	0.00	0.00	0.00
Totals	15.30	18.00	18.50	19.00	19.60	20.00	20.60

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	3.6	3.6	4.0	4.1	4.5	4.5	4.5
Other[a]	1.5	1.5	1.5	1.5	2.0	2.0	2.0
Totals	5.1	5.1	5.5	5.6	6.5	6.5	6.5
AF Procurement for ARTS		5.0	5.0	5.0			

c. VTC/VT from 1996 to 2000

The vehicle teleoperation (VT) program, classified as a non-major acquisition program according to the master plan, still appears to be the top UGV program overall. According to the 2000 document, this program is on an accelerated time line. It has accelerated due to combat experience in Bosnia, which allowed the technology to quickly mature and support technology development for multiple platforms simultaneously. These platforms include HMMWVs, M1 tanks, M60 tanks and D7Gs (DOD, 2000). The latest platforms under consideration for this application belong to the engineer family of clearance vehicles. These vehicles include the T3 bulldozers, the DEUCE and M9 ACE earth movers.

While the 2000 joint robotics program master plan (JRPMP) describes this as a program with an accelerated schedule, a comparison of the 1996 to the 2000 plan shows that the schedule has slipped further into the future in the current plan. The comparison of the program schedules in the years mentioned is shown in Figure 74. The small business innovative research (SBIR) was broken into three phases in 1996 with Phase 3 concluding in FY98. In the 2000 master plan, Phase 2 was extended into FY98, and Phase 3 has been extended to the end of the planned schedule out to FY01. Milestone I/II did occur in 1997 as it was planned in 1996, but in the 1996 plan, Milestone III was planned for mid-FY98. In the 2000 master plan, Milestone III is now planned for mid-FY01.

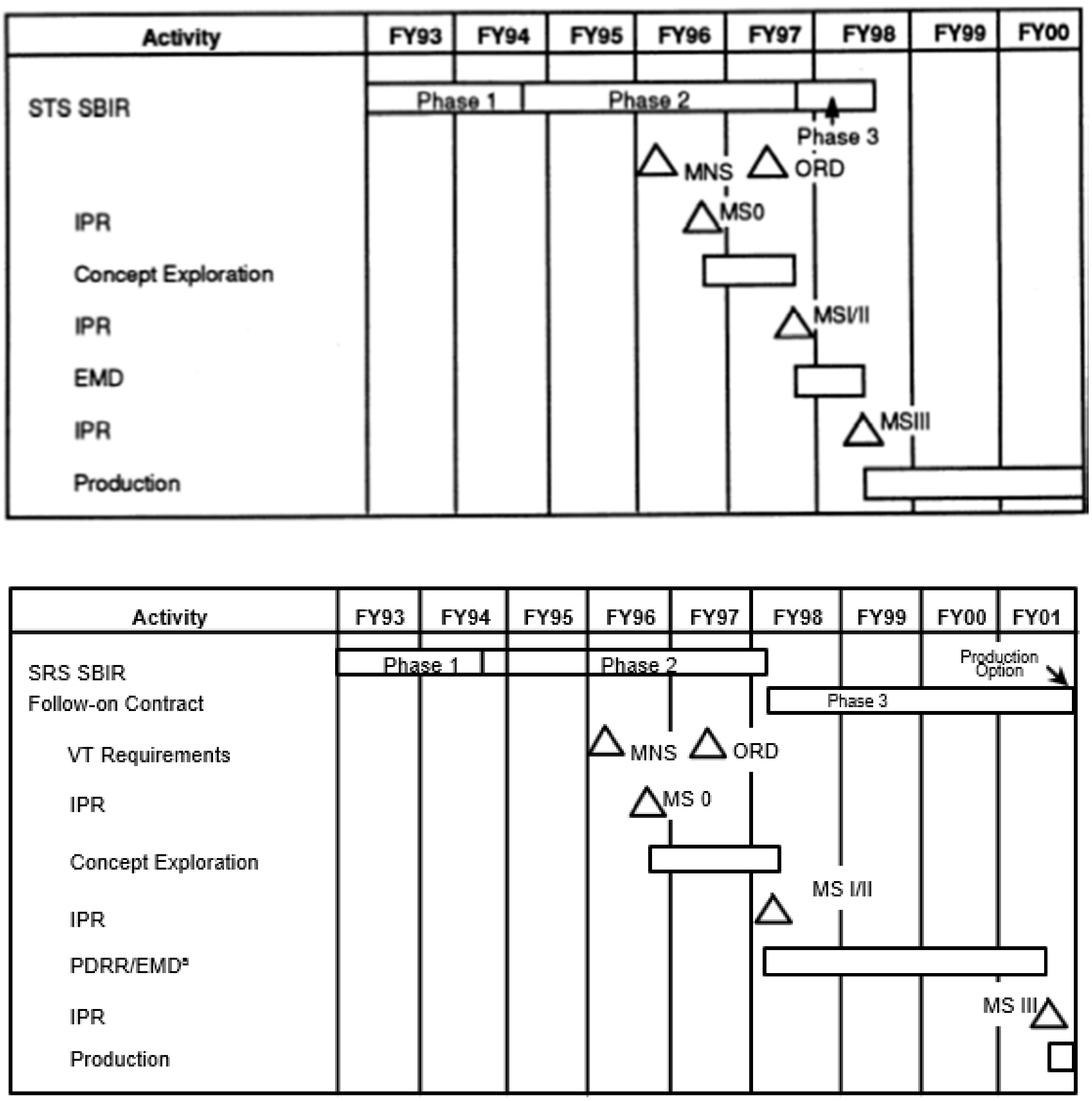


Figure 74. 1996 VTC Schedule Compared to 2000 VT Schedule (from DOD, 1996, 2000)

Table 18 compares the funding planned in the 1996 master plan against what was planned in the 2000 master plan. The amounts planned for FY99 and FY00 in 1996 have actually doubled in the 2000 master plan. From FY01 and forward, the funding is aligned with what was planned in 1996, but it would not be surprising for these figures to increase as the year of execution draws near. Only JRP funding was considered in 2000 because more detailed data about program funding was not available in the 1996 master plan.

Table 18. 1996 VTC Funding Compared to 2000 VT Funding

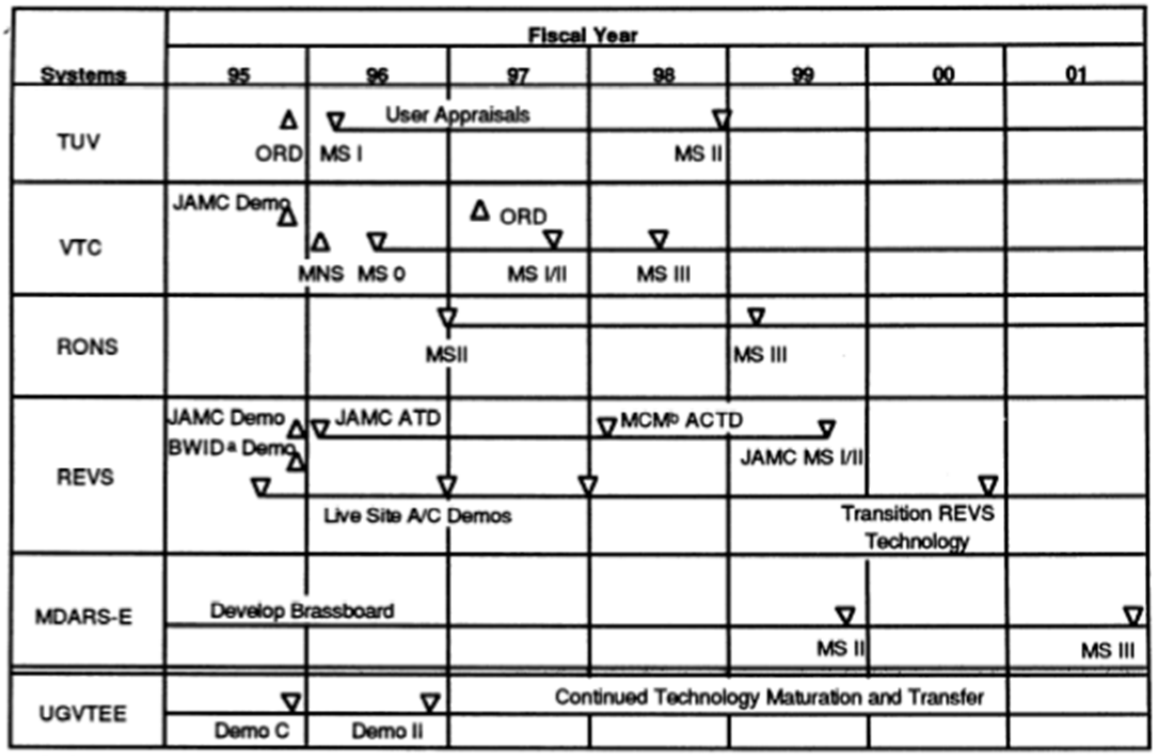
ASD Program	FY96	FY97	FY98	FY99	FY00	FY01	FY02
TUV	8.40	8.70	10.30	10.70	11.10	11.00	11.60
VTC	4.00	5.40	4.80	4.80	5.00	5.00	5.00
REVS	2.50	3.50	3.00	3.50	3.50	4.00	4.00
RONS	0.40	0.40	0.40	0.00	0.00	0.00	0.00
Totals	15.30	18.00	18.50	19.00	19.60	20.00	20.60

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	9.7	10.3	3.0	5.0	5.0	5.0	5.0
Army	2.8[a]	0.7[b]					
Total RDT&E	12.5	11.0	3.0	5.0	5.0	5.0	5.0
Procurement	0.0	4.0	0.7	2.4	0.0	0.0	0.0

Overall, the VT program is delivering products with results that can be measured. This system is proven in combat which makes it more attractive to other platforms that the services use. At this point, the system requires an operator to control it from another vehicle, but building upon this to a more semiautonomous and autonomous role is expected.

d. UGVTEE/DEMO III from 1996 to 2000

In the 1996 master plan, the UGVTEE program concluded DEMO II was very successful in technology development for UGVs. The future schedule for the UGVTEE depicted the sole goal of continued technology maturation and transfer into systems within the program, particularly systems conducting reconnaissance in the FTUV program. The 1996 master plan also stated goals under UGVTEE of night mobility, increased speeds on improved surfaces and over rough terrain, increased obstacle detection and avoidance, with the ultimate goal of achieving supervised autonomous operations (DOD, 1996). These are good intentions and a great follow up to the DEMO II program, but a more structured, aggressive technology development program was once again needed. The UGVTEE program schedule as depicted on the overall UGV schedule and the DEMO III schedule presented in 2000 is shown in Figure 75.



[a] Buried Waste Integrated Demonstration

[b] Mine Countermeasures

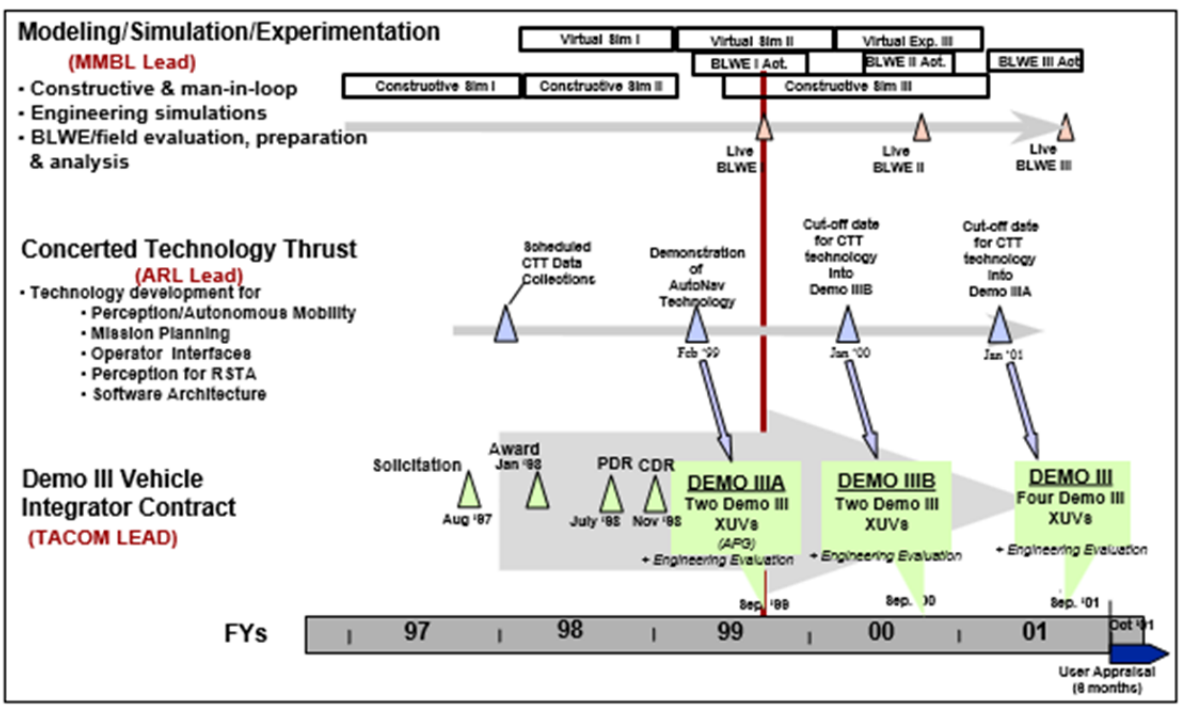


Figure 75. 1996 UGVTEE Schedule Compared to 2000 DEMO III Schedule (from DOD, 1996, 2000)

In 1996, there was dedicated funding to the UGVTEE program presented in the master plan, but it is not tied to a visible timetable with milestones. The DEMO III funding presented in the 2000 master plan is shown in Table 19. The Army has been designated as the responsible service for the DEMO III program, which is why the JRP funding expires in FY01 and the Army funding increases significantly for the remainder of the program. The new schedule and dedicated funding provide the structure necessary to force aggressive developments for this complicated technology.

Table 19. DEMO III Funding (from DOD, 2000)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
Demo III							
JRP	9.2	10.1	0.0	0.0			
Army[a]	0.9	5.0	16.5	1.0			
Total	10.1	15.1	16.5	1.0			
Robotic Technology Development							
Army[a]				17.0	20.0	20.0	20.0
Total				17.0	20.0	20.0	20.0

[a] Includes funds transferred to Army by OSD.

"Demo III is a multiyear program designed to develop, assess, and demonstrate new robotic technologies and address specific troop-identified operational limitations" (DOD, 2000, p. 43). The DOD and industry contractors have developed four experimental unmanned vehicles (XUV) that will serve as the program's test bed platforms. The XUV is shown in Figure 76. These vehicles will undergo annual test and evaluation by engineers and ultimately, a culminating six-month user appraisal will conclude the DEMO III program in 2002. The users will provide constant feedback to allow for continued improvements to the technology. This also requires the vehicles to be durable and rugged, capable of performing over several years and for a long duration at the end.

Figure 76. XUV Picture (from DOD, 2002)

DEMO III has three main goals.

> 1) Cross-country maneuver over vegetated terrain at speeds of up to 20 mph during daylight, 10 mph at night or in moderately inclement weather, and at speeds of up to 40 mph when driving on road. 2) Weight under 2,500 pounds and be V-22 transportable. 3) Perform RSTA operations commensurate with the scout mission. (DOD, 2000, p. 45)

The RSTA mission is considered to be one of the most complex military tasks and the most complicated task for a UGV to perform. Completion of these goals will be a lofty task with a large reward if achieved.

Since there is a gap in the data collected for this project, DEMO III is already underway with DEMO IIIA completed in September 1999. Soldiers successfully operated two test bed XUVs in conjunction with manned scout vehicles. The focus of the exercise was on a vehicle operator's ability to control semi-autonomous vehicles. The operators were able to plan and execute missions for two XUVs from a single unit interface. The vehicles also drove off-road at speeds up to 10 mph during daylight conditions (DOD, 2000). There is still plenty of work ahead for this program, but early successes exist. It seems that the forced structure and aggressive goals have yielded the best results. Although there are failures in this program, the push to increase and mature technologies are quickly realized according to results presented in the master plan.

e. MDARS-I/E from 1996 to 2000

Overall, the MDARS-I/E program appears to progress well and the program schedule has stabilized over the past few years. The highlighted tests accomplishments in the master plan include navigational path following, movement over various terrain types, security functions, and autonomous functions (DOD, 2000). The MDARS-I schedule from 1996 compared to the MDARS-I schedule from 2000 is shown in Figure 77. Milestone II occurred as planned but Milestone III did shift one year further into the future. The 2000 master plan also includes the MDARS-I funding which was not present in the 1996 master plan. JRP funding for the program is planned to expire in FY01 when it will be continued by physical security equipment (PSE). The MDARS-I funding plan present in 2000 is shown in Table 20.

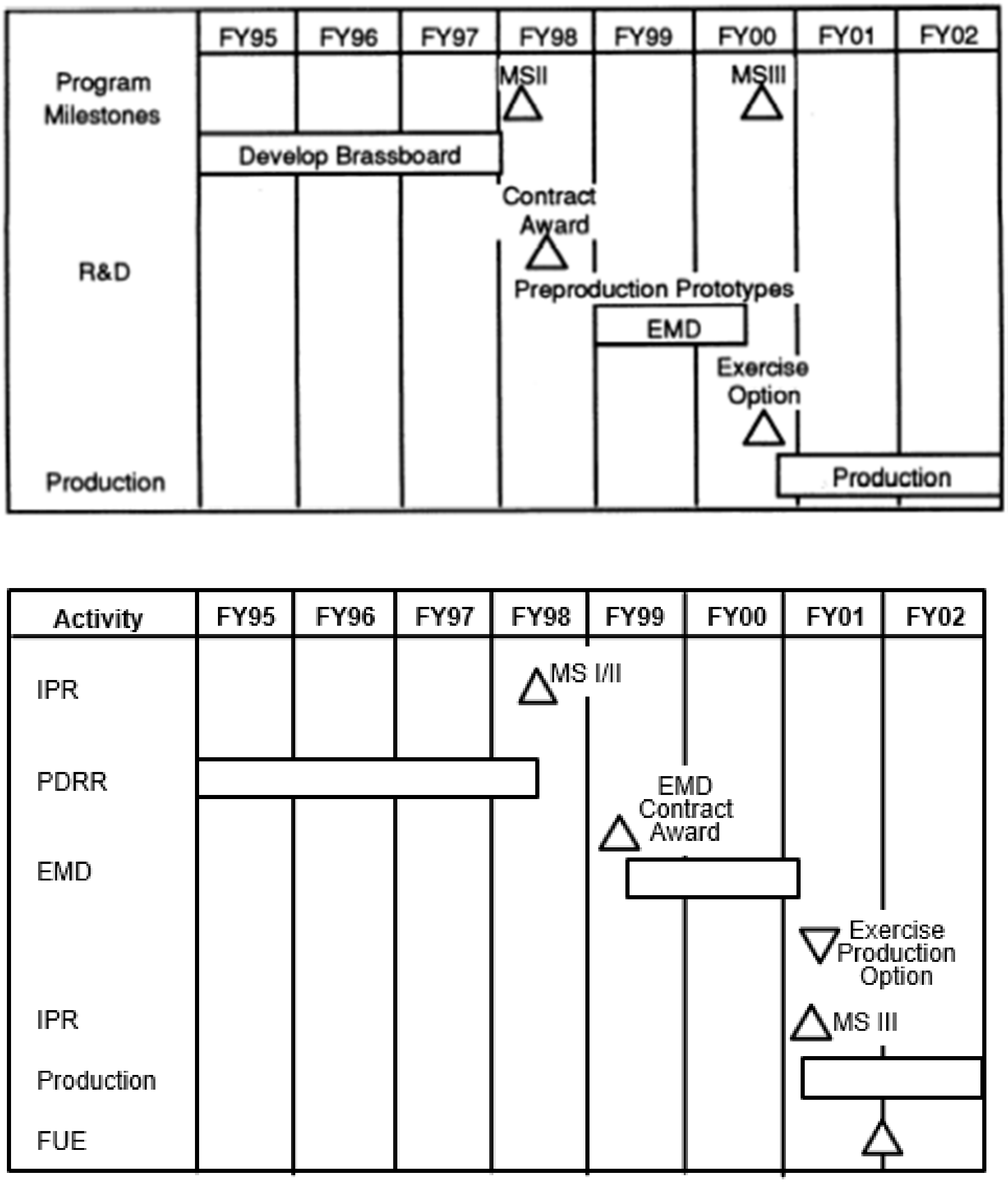


Figure 77. 1996 MDARS-I Schedule Compared to 2000 MDARS-I Schedule (from DOD, 1996, 2000)

Table 20. MDARS-I Funding (from DOD, 2002)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	3.1	1.7	1.5				
PSE	0.0	0.0	0.0	3.3	2.2	2.2	2.2
RDT&E Total	3.1	1.7	1.5	3.3	2.2	2.2	2.2

The MDARS-E program saw its Milestone II slip from FY99 in the 1996 plan to FY00 in the 2000 plan. Milestone III planned for FY01 in 1996 is now planned for FY02 in the 2000 master plan. The slippage of schedule pushed the EMD contract award back by one year and has shifted production one year further into the future as well. This data is presented in Figure 78. Like the MDARS-I, the MDARS-E funding is presented in the 2000 master plan and is depicted in Table 21.

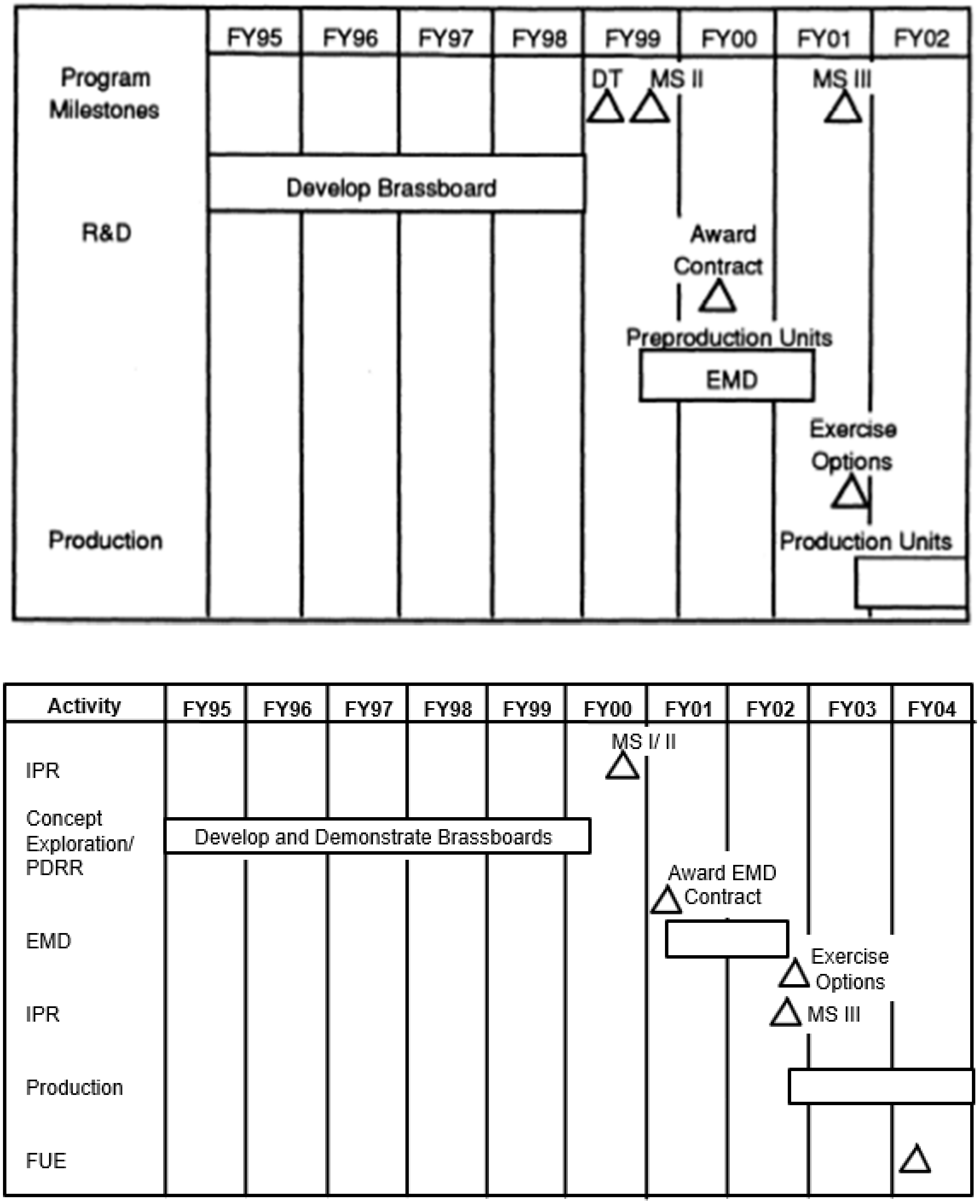


Figure 78. 1996 MDARS-E Schedule Compared to 2000 MDARS-E Schedule (from DOD, 1996, 2000)

Table 21. MDARS-E Funding (from DOD, 2002)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	0.0	0.0	1.0	3.0	0.0	0.0	0.0
PSE	5.5	4.9	5.6	0.0	3.7	4.4	4.4
RDT&E Total	5.5	4.9	6.6	3.0	3.7	4.4	4.4

The MDARS-I/E have successfully demonstrated their ability to patrol inside and outside of facilities, in an autonomous fashion. The environments are highly structured which makes autonomous operation possible, and while employing this technology autonomously in a dynamic and changing environment is still a far reach, there is a lot of potential. Technology development and maturation in DEMO III should assist with progressing to the next level.

f. RONS + FTUV + REVS = BUGS from 1996 to 2000

Basic UXO gathering system (BUGS) is a system developed from technologies of many other systems in the UGV program. Remote ordnance neutralization system (RONS) is probably the largest contributor to this program; it is a Navy-based program and its primary function is EOD based. The picture of the BUGS system which looks very similar to the RONS system from 1996 is shown in Figure 79. The off-road and autonomous capabilities of this system are derived from the FTUV program and the gains made in the desire to conduct the reconnaissance mission on any terrain. Lastly, the BUGS system gains technology from the robotic excavation vehicle system (REVS) program that was designed to search areas, identify, dig up, and remove UXO from ranges and mine fields.

Figure 79. Picture of BUGS (from DOD, 2002)

The BUGS system is a man-portable, EOD supported UGV.

> The system consists of a semiautonomous reconnaissance platform and several man-portable, expendable autonomous vehicles. The reconnaissance platform can detect and localize surface UXO and download information to small robots. The latter then goes to the target area location, performs a close-in search, reacquires the target, and performs BIP (Blow in Place) or PUCA (Pick Up and Carry Away) operations before proceeding to the next target. (DOD, 2000, p. 25)

EOD operators then utilize one control unit and essentially release a swarm of BUGS to conduct reconnaissance of a large area. Once detected, the larger BUGS unit similar in appearance to the RONS will deploy to the UXO and neutralize the object.

Although derived from many other programs and technologies, this is a brand new program with a basic schedule. The BUGS schedule with Milestone 0 planned for FY02 and Milestone I planned for FY04 is shown in Figure 80. Again, as a young program, it is still a concept at this time. The funding for the BUGS program which consists of JRP funding primarily from FY99 to FY01, at which point the Navy assumes some funding responsibility from FY01 through FY05 is shown in Table 22.

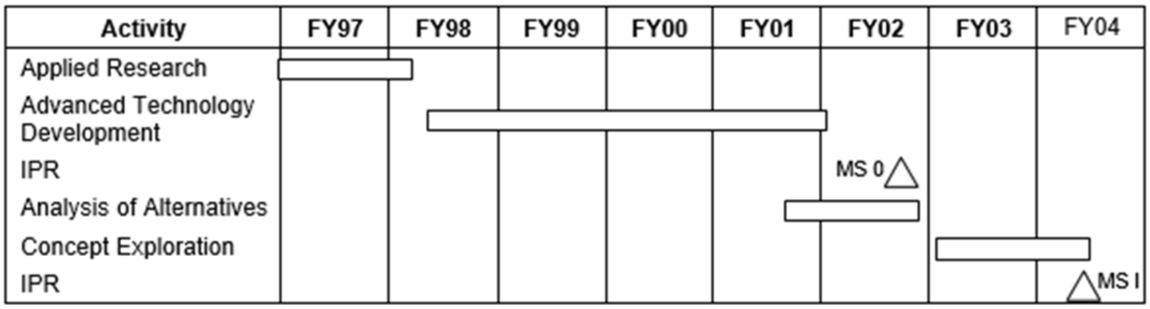


Figure 80. Bugs Schedule (from DOD, 2002)

Table 22. BUGS Funding (from DOD, 2002)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	0.7	0.7	0.7	1.0	2.0	2.0	2.0
Navy			0.2	0.9	1.0	1.1	1.1

The 2000 master plan states that sensors stand as the biggest challenge for this program. “Detection of small UXOs and obstacles from a small inexpensive platform is challenging. Current efforts focus on collecting data on small, inexpensive sensors capable of meeting requirements” (DOD, 2000, p. 26). This further shows the overall technological challenges the UGV program faces as it places higher value on the DEMO III program and other technology advancement programs. If not realized, technological gains and many good ideas can fail to evolve into delivered systems.

g. REVS + VT = RCSS from 1996 to 2000

Although the robotic combat support system (RCSS) did not exist in the 1996 master plan, it is technically viewed as a new program and appears to have developed from the VT and REVS programs. The mini-flail, a system referenced in 1996 in the vehicle teleoperation capability (VTC) program, is the main RCSS system discussed in the 2000 master plan. Other developments in the RCSS program call for larger vehicles with characteristics similar to vehicles previously mentioned in the REVS program.

Developed for use by SOF personnel, the mini-flail systems were successfully utilized in Bosnia to proof areas for anti-personnel mines as well as create lanes for dismounted troops and lightweight vehicles. The larger systems in the RCSS program that have REVS roots are expected to remove UXOs from large areas, clear airfields, assist with urban breaches and to clear lanes for dismounted personnel (DOD, 2000).

The RCSS program schedule is shown in Figure 81. Because this is a new program that merged from other programs, it makes more sense to show this schedule independently. The RCSS funding planned for the 2000 master plan is shown in Table 23. Interestingly, the overall program funding groups the VT and RCSS program together under Engineer UGVs as seen in Table 16. The master plan, however, breaks out the funding separately for each program with RCSS funding at about 15% of all Engineer UGVs funding.

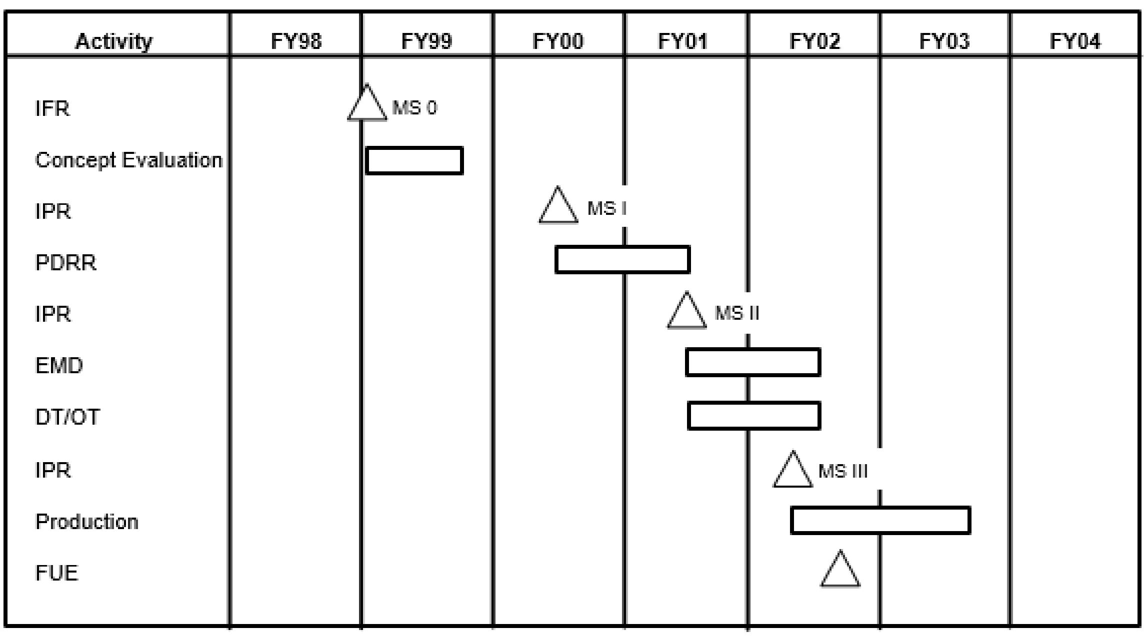


Figure 81. RCS Schedule (from DOD, 2002)

Table 23. RCS Funding (from DOD, 2000)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	1.9	3.0	6.1	3.2	3.0	0.0	0.0
Army	1.4[a]	0.6[b]	0.0	0.0	0.0	0.0	0.0
Total RDT&E	3.3	3.6	6.1	3.2	3.0	0.0	0.0
Procurement	0.0	0.0	0.0	4.7	2.1	0.0	0.0

h. Conclusion

The UGV master plans from 1997 to 1999 were unattainable for this project. In just a few short years, significant changes to the program occurred, particularly to the structure and naming convention of the programs. As technology developments and new requirements arise, new programs are created that stem from many other programs in the portfolio.

For the most part, schedules slipped further into the future than planned in 1996. Funding plans also changed, especially toward programs deemed essential to offering Bosnian support. During this time, the operational environment continues to shape the priority of programs as seen as the VT and RCSS gain the most traction due to the capabilities they provide for warfighters in Bosnia. The creation of the DEMO III program is possibly the most significant addition to the program. Historically, the greatest gains appear to have come from DEMO I and DEMO II so much of the same is expected for this aggressive technology development program.

3. Summary from 1996 to 2000

The program funding presented in Figure 82 is based on planned funding from the 1996 UGV master plan and 2000 JRP master plan. The most significant funding change is to the FTUV program as funding is slashed by more than 50% between FY99 and FY00. ROCS funding is generally stable in all years. The conflict in Bosnia and the demand for VT is reflected in the increase funding to this program in almost every year presented. The funding for RONS appears to increase substantially, but is based off service funding from the 1996 master plan, which is planned for system procurement for each service. Funding for fielding is expected to be higher than funding for R&D. All other programs primarily show R&D funding.

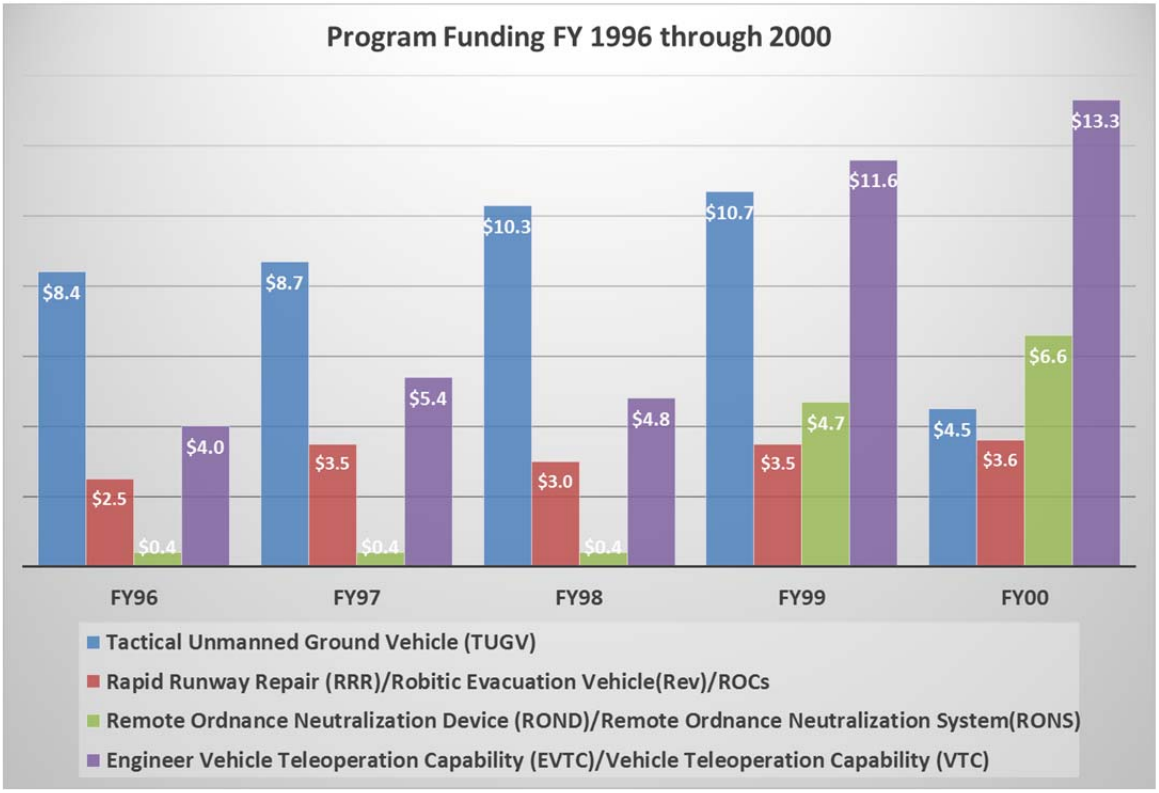


Figure 82. UGV Program Funding Comparison 1996–2000 (after DOD, 1996, 2000)

a. FTUV from 1996 to 2000

The 2000 JRPMP does not present a schedule for the FTUV so it is assumed that the schedule is unchanged since the last one presented in the 1996 UGVMP. The program appears to have fallen in priority as the war in Bosnia creates unexpected demands for other UGVs from the warfighter. In the 1996 master plan, funding for the FTUV was planned to be in excess of $10 million per year from FY98 to FY02. The actual funding presented in the 2000 master plan shows that the funding was cut drastically for this program. Without the 1997–1999 master plans, it is difficult to determine if the program actually received the amount of money shown in the 1996 master plan. The planned funding for FY99 was most likely impacted for the FTUV, since it is the first year when

VTC program funding rises significantly. The FTUV schedule change between 1996 and 2000 is shown in Figure 83. The funding change in the same time period is shown in Figure 84.

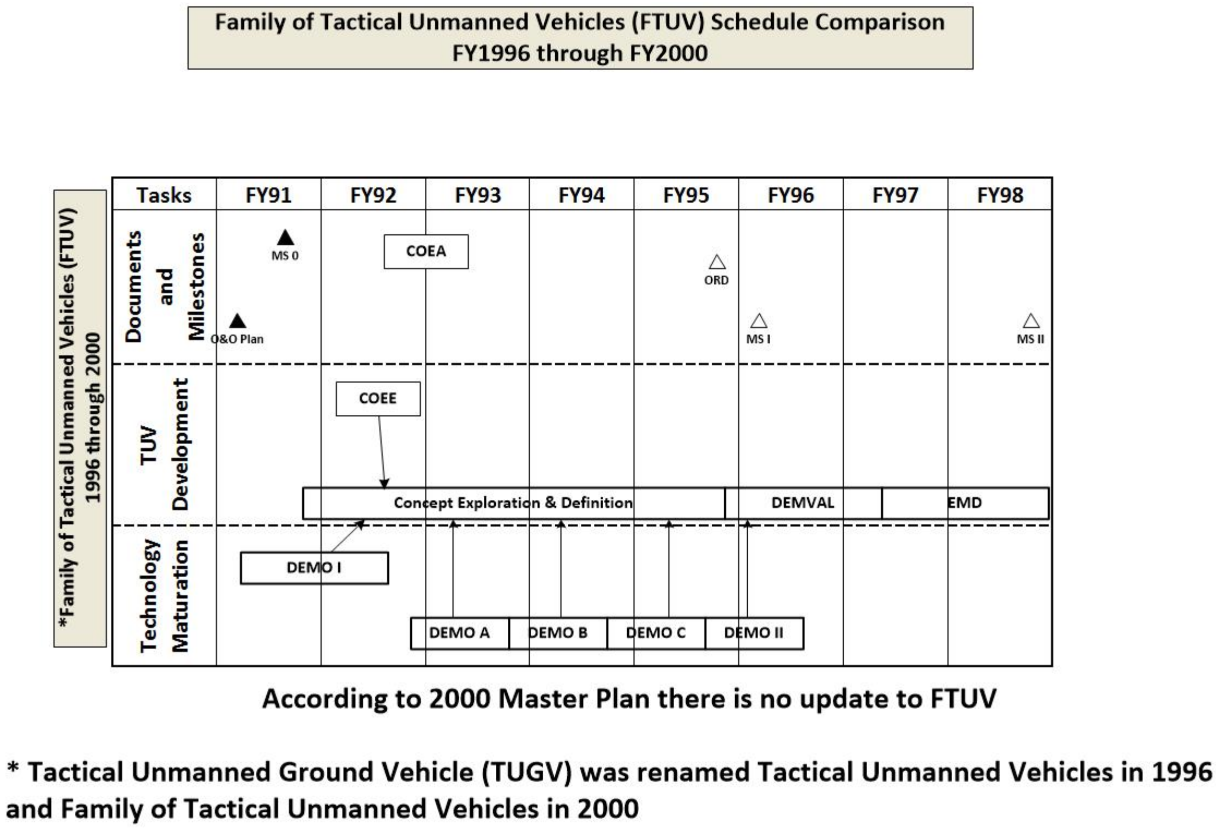


Figure 83. FTUV Schedule Comparison 1996–2000 (after DOD, 1996, 2000)

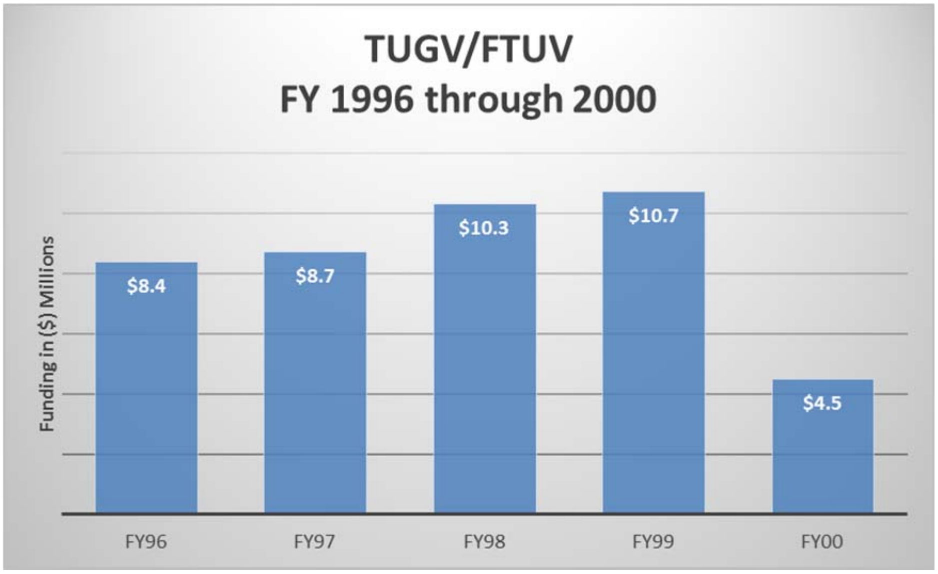
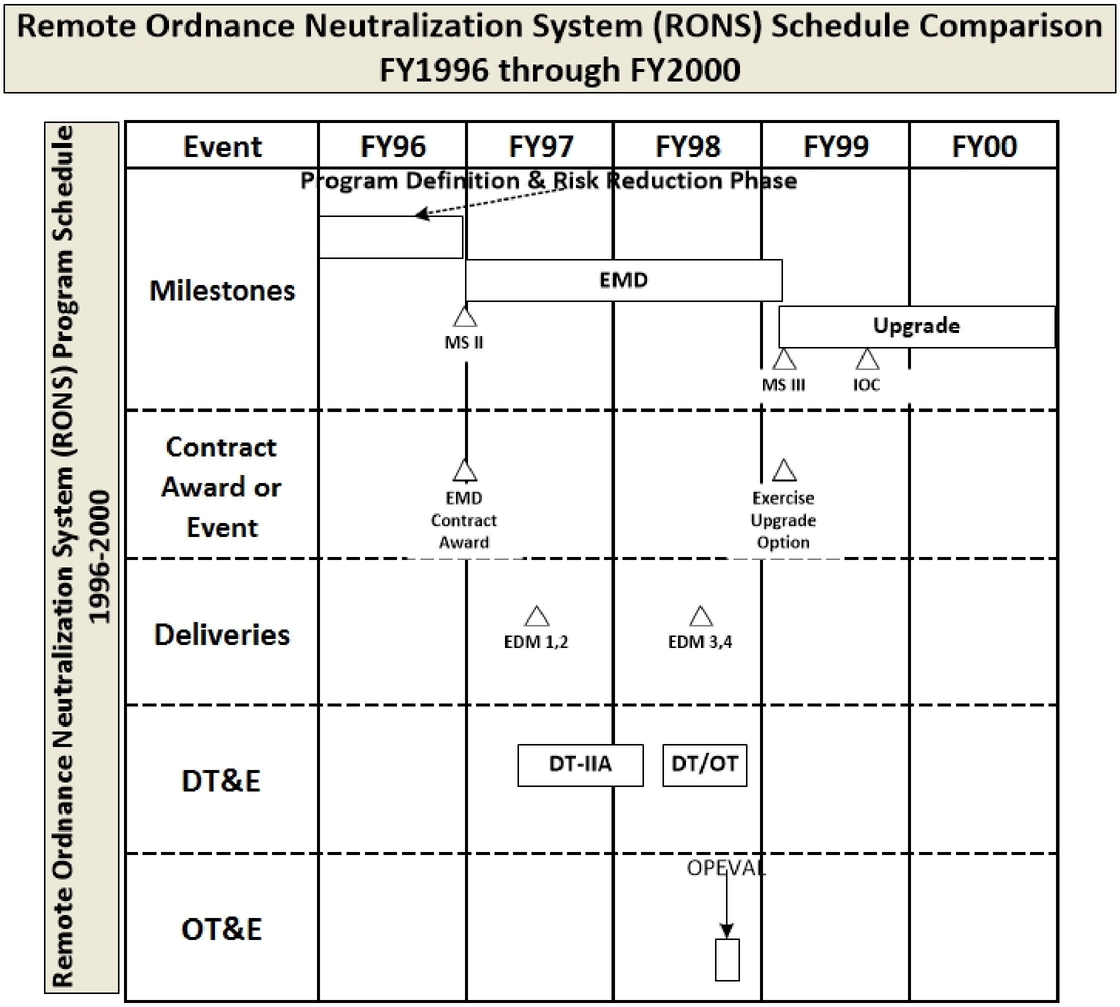


Figure 84. TUGV/FTUV Funding Comparison 1996–2000 (after DOD, 1996, 2000)

b. RONS from 1996 to 2000

In the 1996 UGVMP, the RONS schedule depicted a planned Milestone III date in FY99 and was actually accomplished on schedule. At this point in time, the program is in initial operational capability (IOC) and full rate production is ongoing. Future information on this program is aimed at production quantity and improvements to the system fielded in future increments. As previously stated, the funding for RONS jumps significantly once it achieves Milestone III because individual services began procurement of RONS systems and is more expensive than the R&D portion of funding. The RONS schedule change between 1996 and 2000 is shown in Figure 85. The funding change in the same time period is shown in Figure 86.



***RONS achieved Milestone III and Initial Operational Capability (IOC) in FY99.**

Figure 85. ROND/RONS Schedule Comparison 1996–2000
(after DOD, 1996, 2000)

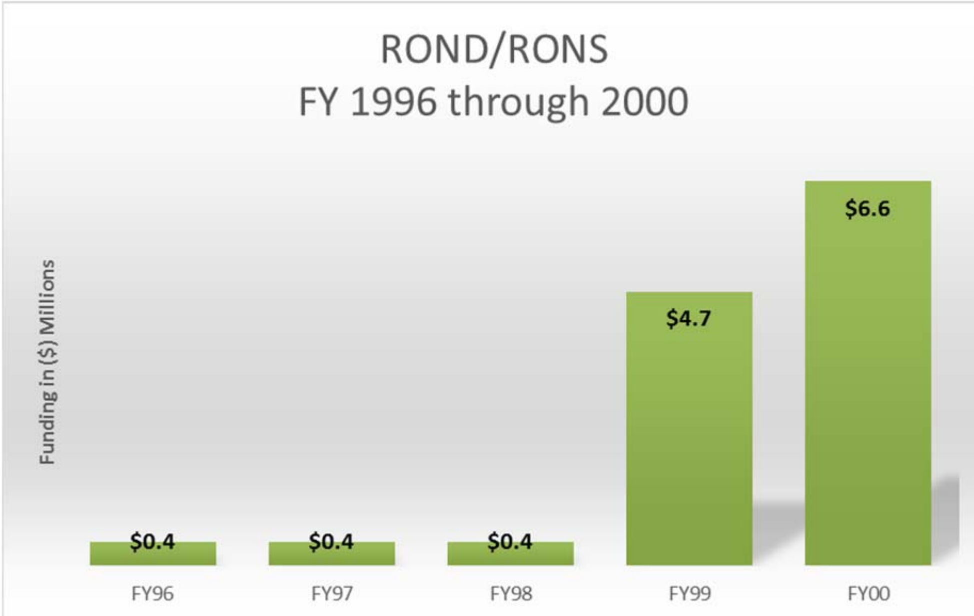


Figure 86. ROND/RONS Funding Comparison 1996–2000 (after DOD, 1996, 2000)

c. *REVS/ROCS from 1996 to 2000*

As stated, REVS became ROCS between 1996 and 2000. Under ROCS four major systems are prevalent: ARTS/ARC, ARTS/F-P, AROMS, and AOE. The REVS and ROCS schedules presented in Figure 87 are more challenging to interpret, but it is determined that the ARTS system is a success under this program. Success is defined as delivered capability to the users in a timely manner. Based on the 1996 master plan, an assumption was made that Milestone III would occur in FY98. Through analysis of the 2000 master plan, it is determined that the ARTS/ARC and ARTS/F-P achieved this milestone. The baseline is complete and prototype deliveries are depicted in the FY98 and FY99 timeframe. From 1996 to 2000, the funding depicted in Figure 88 is relatively stable. This is interesting because the funding did not increase significantly with the production and delivery of systems to users like it did with the RONS program. This may mean that the system is inexpensive, or that it simply required a conversion of an already existing system. Funding under this program now includes production for ARTS variants and R&D for AROMS and AOE.

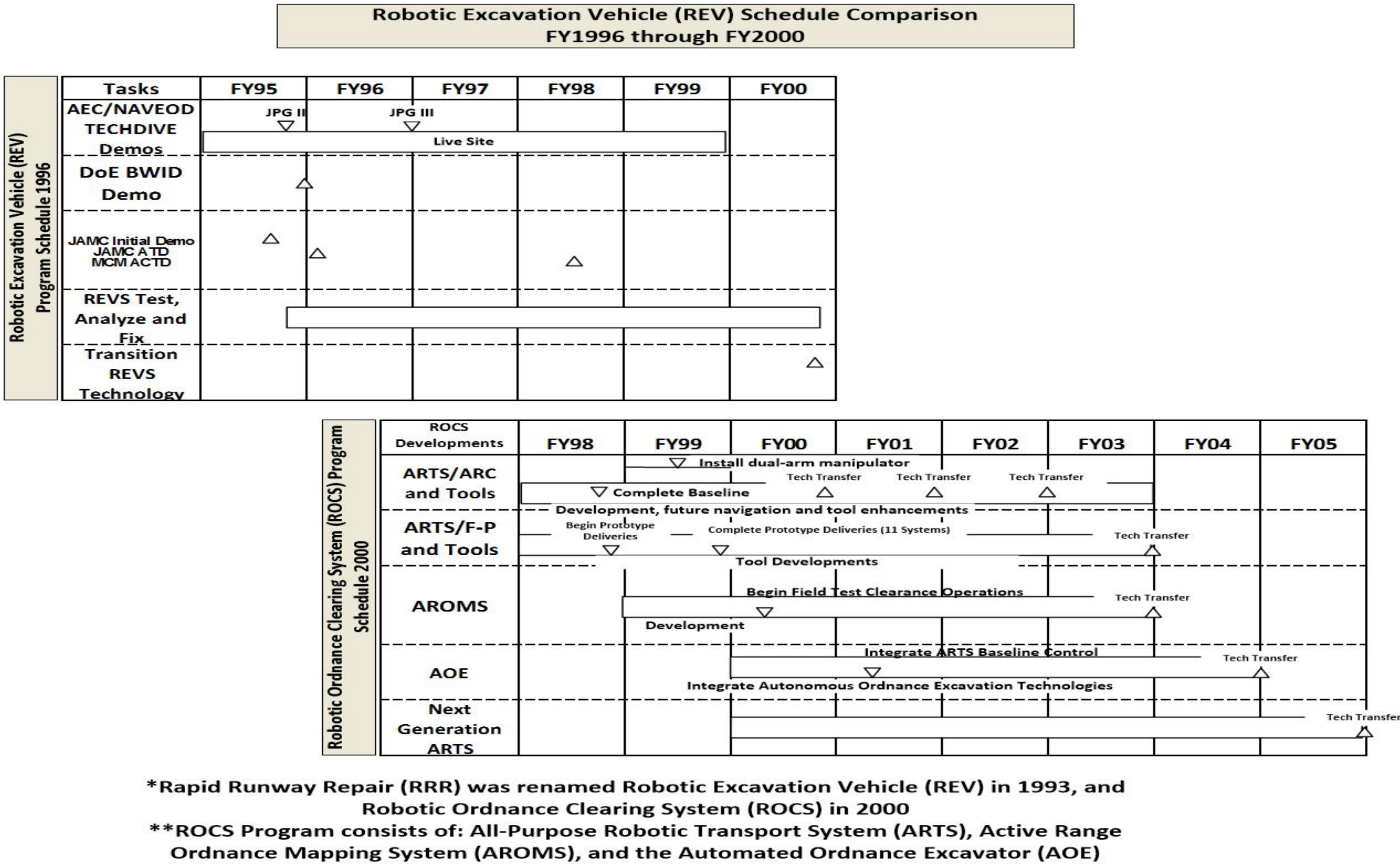


Figure 87. RRR/REV/ROCS Schedule Comparison 1996–2000 (after DOD, 1996, 2000)

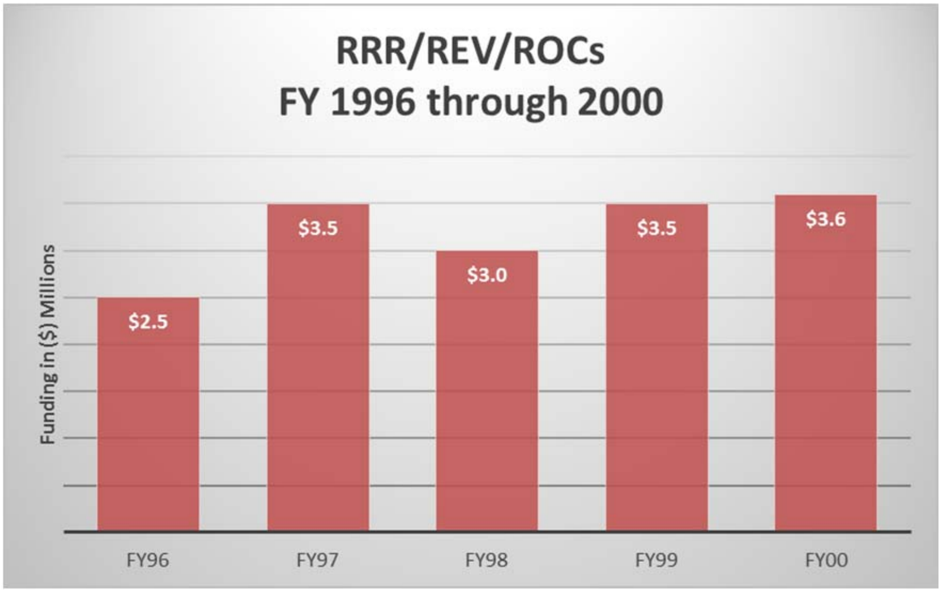


Figure 88. RRR/REV/ROCS Funding Comparison 1996–2000 (after DOD, 1996, 2000)

d. VTC/VT from 1996 to 2000

The VT program is interesting because it becomes the highest priority program from 1996 to 2000 due to the conflict in Bosnia. The funding for this program increases as more vehicles are outfitted with the technology to meet the warfighter's needs. The vehicle performed well in combat and proved its value in a combat environment by reducing warfighter's exposure to risk. However, the master plans discuss the need for schedules accelerate but instead the schedule slips. The VT schedule slip from 1996 to 2000 is shown in Figure 89. Milestones I and II shift by less than a year but a significant shift in Milestone III in noted from FY98 to FY01. This is not indicative of high priority and full rate production on an accelerated time line. The VT funding changes between 1996 and 2000 is shown in Figure 90.

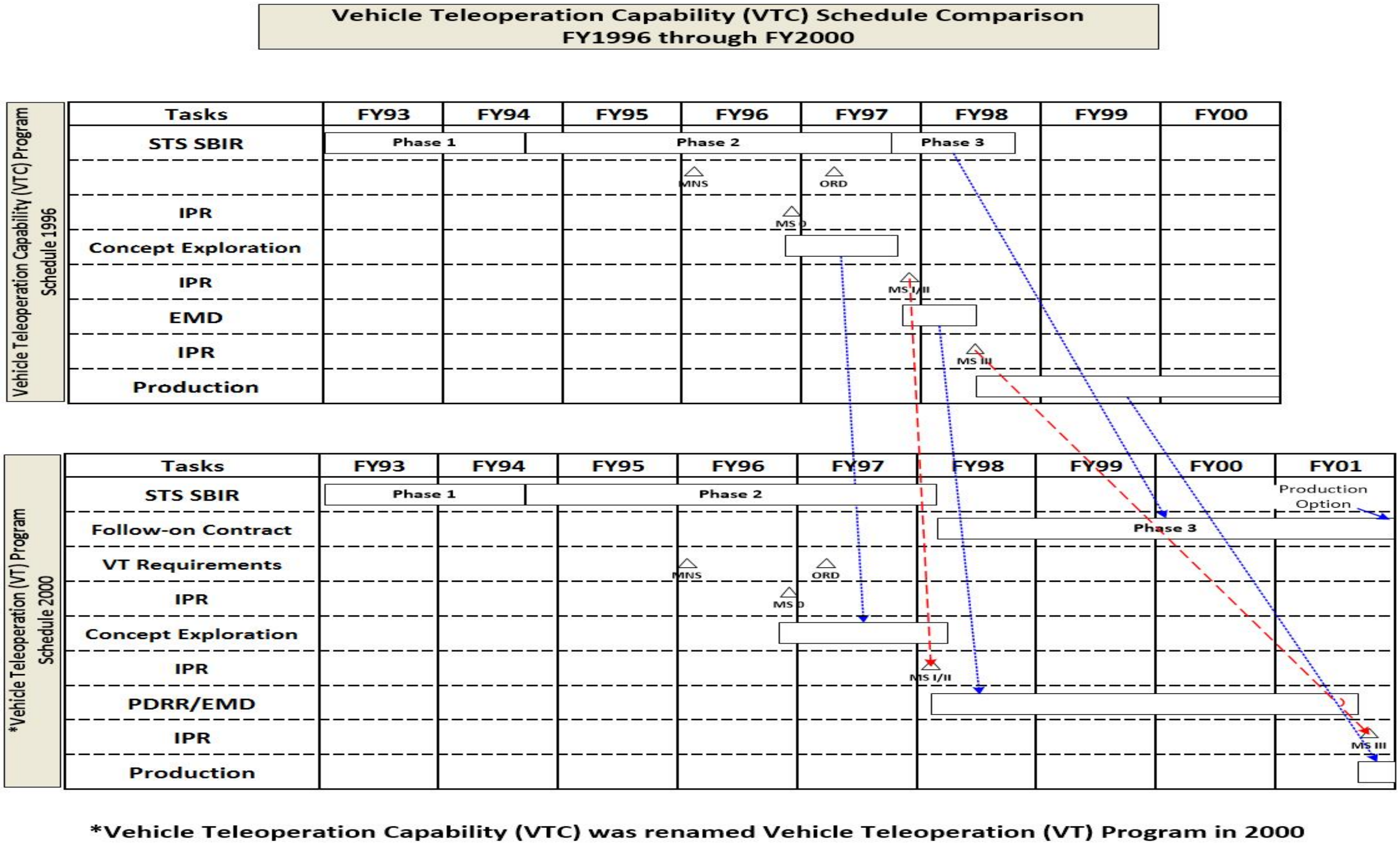


Figure 89. EVTC/VTC/VT Schedule Comparison 1996–2000 (after DOD, 1996, 2000)

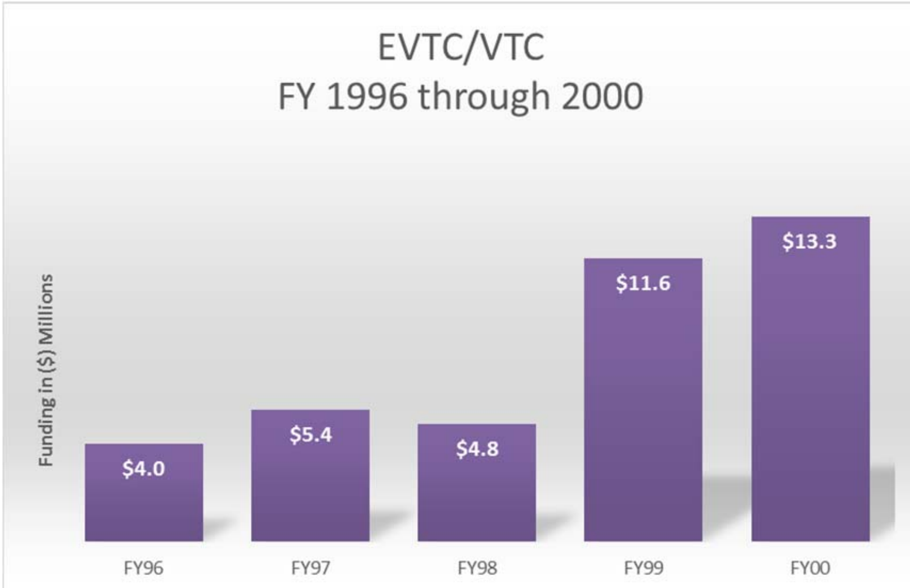


Figure 90. EVTC/VTC/VT Funding Comparison 1996–2000 (after DOD, 1996, 2000)

e. MDARS-E/I from 1996 to 2000

Both the MDARS-E/I schedules experience slippage in multiple categories. The MDARS-E schedule is presented in Figure 91 and the MDARS-I schedule is displayed in Figure 92. For both programs, Milestones I, II and III shift one year further into the future than what was originally planned in 1996. Overall, this is not a huge schedule slip over a five-year period, compared to other program schedules. Based upon the information presented in 2000, production of this program should begin soon. MDARS funding is not presented in any of the master plans.

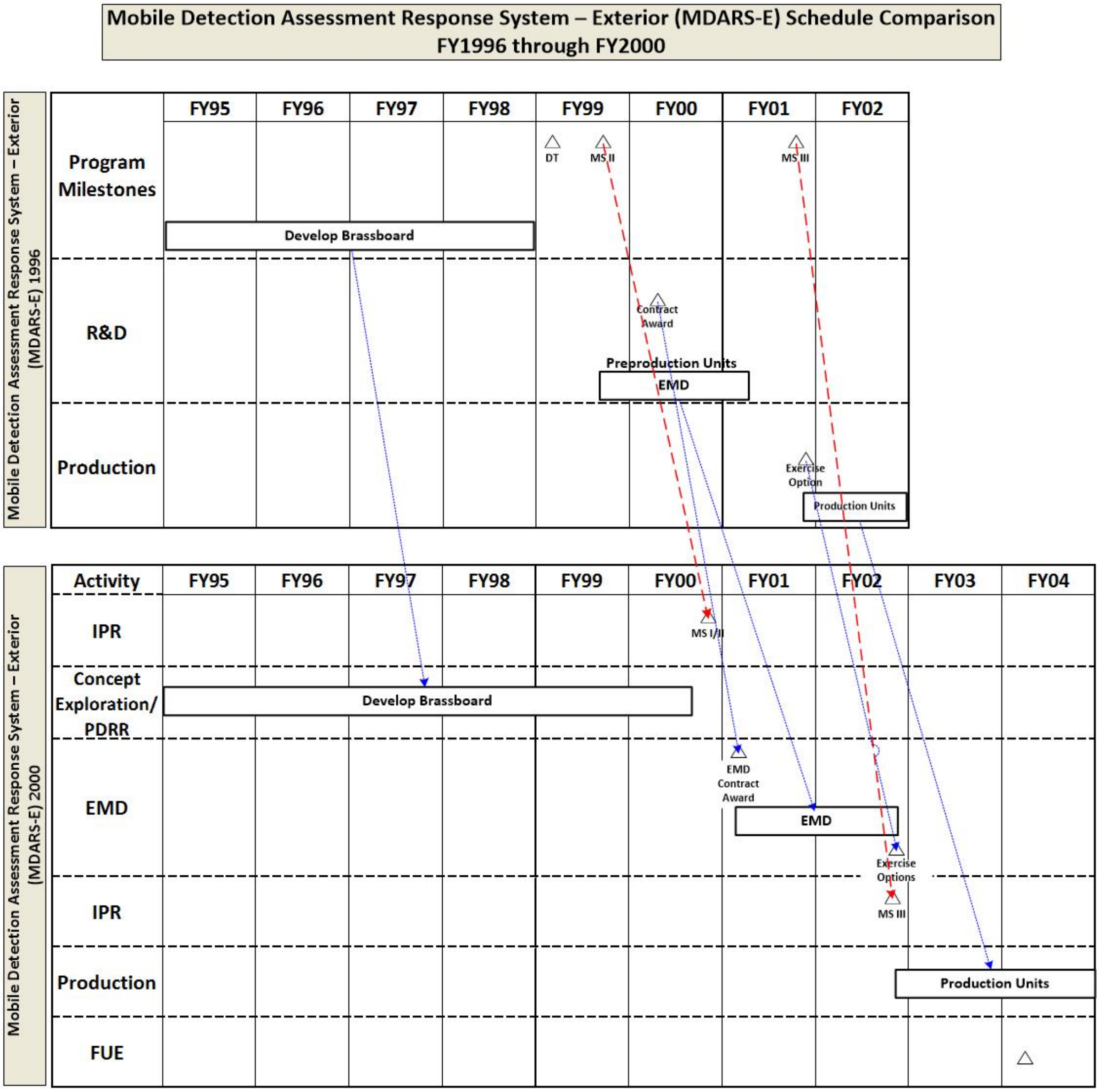


Figure 91. MDARS-E Schedule Comparison 1996–2000
(after DOD, 1996, 2000)

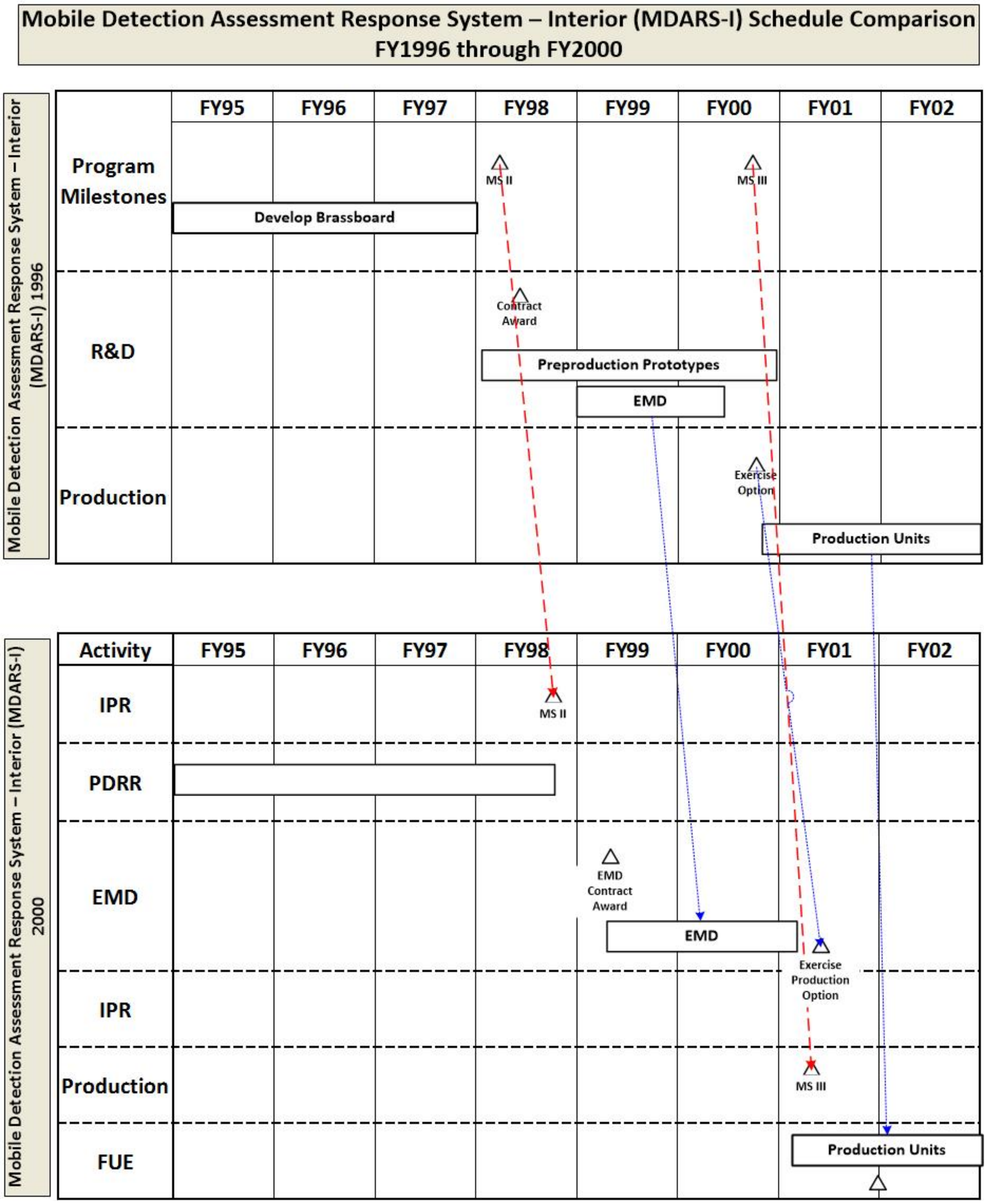


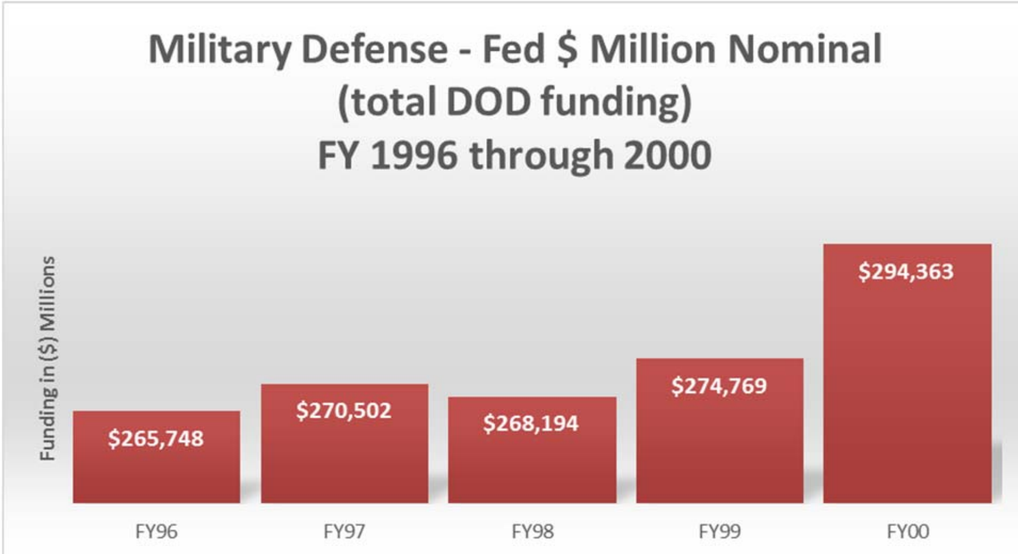
Figure 92. MDARS-I Schedule Comparison 1996–2000 (after DOD, 1996, 2000)

The UGV program as a whole is on an interesting path. The FTUV, supposedly the premier program in the portfolio, has yet to produce a fielded system between 1991 and 2000. However, the RONS EOD system and the ARTS/ARC and ARTS/F-P under the ROCS program quietly progress along and deliver fielded robots to users in the force. The VT program, which is designated as the key program due to the conflict in Bosnia does receive more funding, but the schedule shows milestone slippage.

Overall, two of the systems covered in the summary achieved full rate production and it occurs in two unlikely and less glamorous programs in the master plans. Interestingly, both fielded systems have a very niche capability within the EOD community and among Engineers for range clearance. For the most part, these systems are also simply remotely controlled by operators. This further proves that fielding semi-autonomous and fully autonomous systems is extremely difficult and likely far from reality anytime in the near future. Users appear comfortable with remote controlled UGVs and are a good way to push the technology into the force for future acceptance on a larger scale. The more these systems are seen among the force, the greater chance of pull factors that will help accelerate UGV implementation into further military applications.

f. DOD and UGV Funding Comparison 1996–2000

From 1996 to 2000, the DOD budget and UGS funding are almost aligned, meaning that if one raises the other rises and if one falls, the other falls. A comparison of the two budgets between 1996 and 2000 is shown in Figure 93. The correlation is 0.64, which indicates there is some correlation, but this is only a five-year measured period. This is a different observation when compared to the budgets from 1991 to 1995. Perhaps as the UGS program becomes more stable, it becomes a staple in the DOD budget and is harder to cut funding when the program has tangible results and integration among the force.



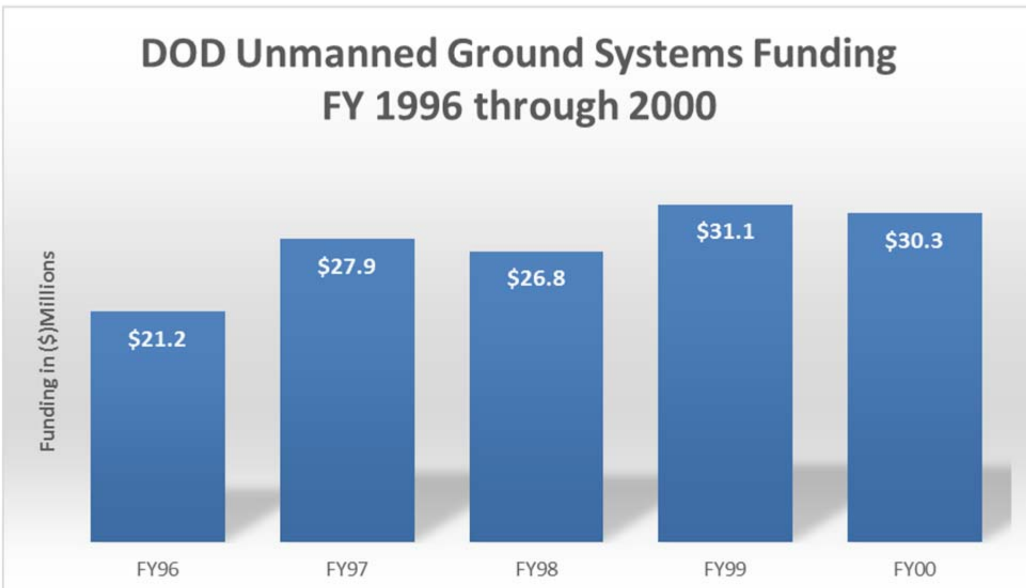


Figure 93. DOD and UGV Funding Comparison 1996–2000 (after DOD, 1996, 2000; www.usgovernmentspending.com, n.d.)

C. 2001 MASTER PLAN THROUGH 2004 MASTER PLAN

In Section C, the research identifies each UGV program mentioned in the master plans from 2001 to 2004, and conducts a comparative analysis of the schedule and funding of each program. The purpose of the research is to identify adjustments to the overall schedule and funding while examining program growth in terms of new systems and UGV program funding. The section concludes with an analysis of schedule and funding from 2001 to 2004 on programs that continued through the years observed.

1. 2001 Joint Robotics Program Master Plan

The 2001 JRPMP presents several changes to the naming conventions of programs that existed in the 2000 JRPMP, with three new programs added in the latest addition. The JAUGS program, once again presented in this master plan, was not mentioned in the 2000 master plan, and thought to be cancelled. The elimination of the DEMO III program remains the biggest surprise in this plan. While not directly addressed as cancelled, the program schedule and funding are not present. There are other technology advancement programs, but they are not a direct replacement or name change of DEMO III. Surprisingly, the FTUV program no longer exists in this master plan, and the program aimed at creating reconnaissance systems has been reduced to one system, and now an independent program, called the Gladiator. The Gladiator is later referred to as a tactical unmanned ground vehicle (TUGV). The requirements that led to the solution for that year is shown in Table 24.

Table 24. Requirements Articulation 2001 Joint Robotics Master Plan

2001
Requirement
Breaching
Countermine Operations
Develop & Field family of UGVS for range of military applications IAW user requirements
Environmental Cleanup
Explosive Ordnance Disposal
Firefighting, handling & loading of aircraft munitions, multiple UXO during clearing operations
Logistics
Military Operations in Urban Terrain (MOUT)
Minefield Detection & Neutralization
NBC Detection and Laser Designation
Obstacle Detection
Physical Security
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
Remote Mine Clearance
Small, lightweight, man-portable UGV to be used for Recon urban environment & other terrain (Infantry/Armor)
TUGV - Supporting the Infantry
UXO
Threat/Conflict
9/11/2001 (9/11 Attacks)
Afghanistan - Operation Enduring Freedom (OEF-A)
Continued peacekeeping operations in the Balkins (Bosnia & Kosovo)
UGV Solution
Family of Tactical Unmanned Vehicles (FTUV) renamed Gladiator Reconnaissance, Surveillance, and Target Acquisition (RSTA) small to medium sized, highly mobile UGV with capability to conduct scout suveillance missions and to carry various mission payloads for a specific task.
Robotic Ordnance Clearing System (ROCS) Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas) - All-Purpose Robotic Transport System (ARTS) - clear paths on ranges or minefields (ARTS-FP)- clearance of large UXO or potential IEDs - Active Range Ordnance Mapping System (AROMS) - Automated Ordnance Excavator (AOE) (1996)
Remote Ordnance Neutralization System(RONS)(Initiated 1990)(renamed from Remote Ordnance Neutralization Device (ROND) Explosive Ordnance Disposal
Basic UXO Gathering System (BUGS) (initiated 2000) (RONS+FUTV+REVS) Part of the RONS program salvaged and merged with parts from the REVS and TUV to create BUGS man-portable, EOD support UGV.
Mobile Detection Assessment Response System - Interior/Exterior (MDARS-I/E) (Initiated 1992) Reduce manpower by patrolling exterior of buildings and compounds in day, night, hot, cold, wet & dry conditions Added security inside military facilities such as large warehouses and depots
Vehicle Teleoperation (VT) Program renamed Standardized Robotic System (SRS) Remote Mine Clearance Breaching Environmental Cleanup
Joint Architecture for Unmanned Ground Systems (JAUGS) (Initiated 1995) Develop common hardware/software open achitecture to ensure intraoperability (vehicle to vehicle) Interoperability (data communications in command, control, communications, computers & intel (C4I) result in cost savings
Robotic Combat Support System (RCSS) (initiated 2000) (REVS + VT)
Unmanned Ground Vehicle Technology Enhancement and Exploitation (UGVTEE) DEMO III CANCELED
Man-Portable Robotic System (MPRS) (initiated 2001) Tasks associated with MOUT (e.g., building clearing, tunnel and sewer rceconaissance, under vehicle inspection, and EOD operations. - Light-Weight Equipment Reconnaissance System (LERS); URBOT and Matilda
Robotic Acquisition through Virtual Environments & Networked Simulations (RAVENS) (initiated 2001) Stakeholders can log onto a computer and participate in collaborative events
Intelligent Mobility Program (initiated 2001) Improve UGVs ability to travers off-road terrain - T3 Vehicle & Omnidirectional Inspection System (ODIS)

Figure 94 compares the 2000 JRP master schedule to the 2001 master schedule. For most of the programs that were present in last year's plan, the schedules have slipped further into the future; this is covered in more detail later in this section. Table 25 compares the 2000 master plan funding with the 2001 master plan funding for the overall UGV program. The changes in the funding are not drastic, but are analyzed in greater detail in each program's respective section.

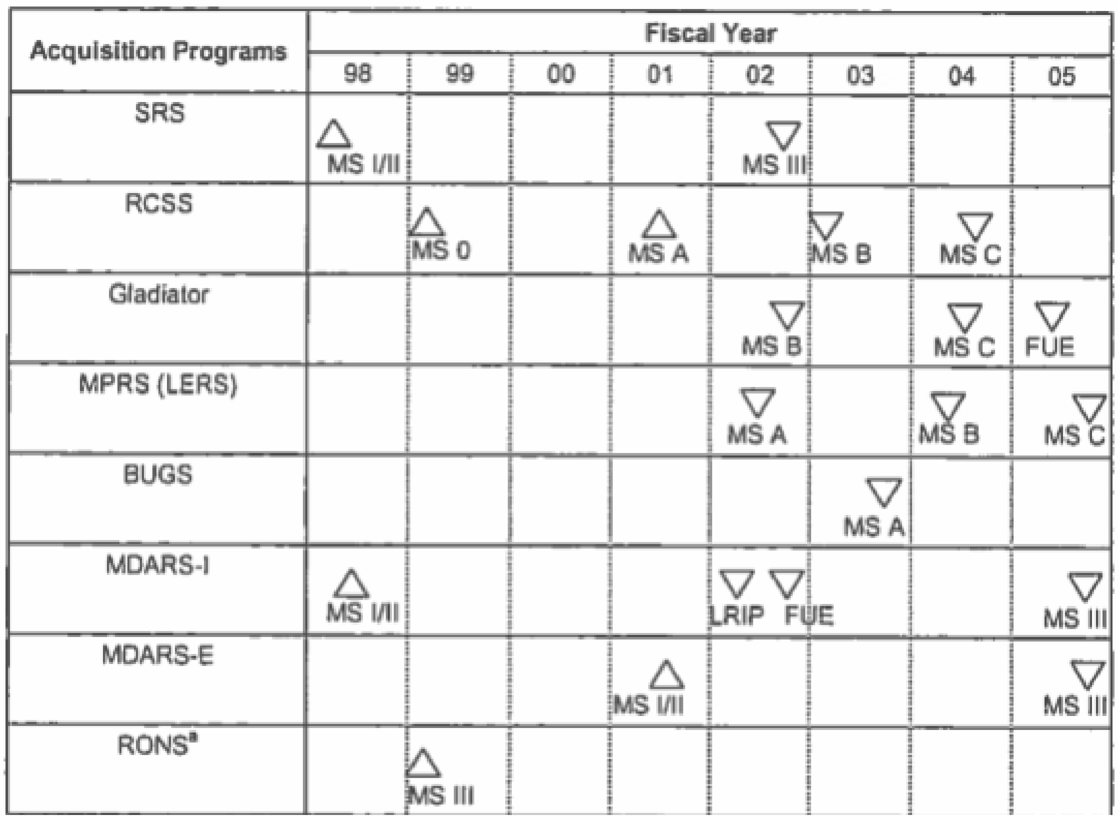


Figure 94. UGV Program Master Schedule (from DOD, 2001)

Table 25. UGV Program Funding Table (from DOD, 2001)

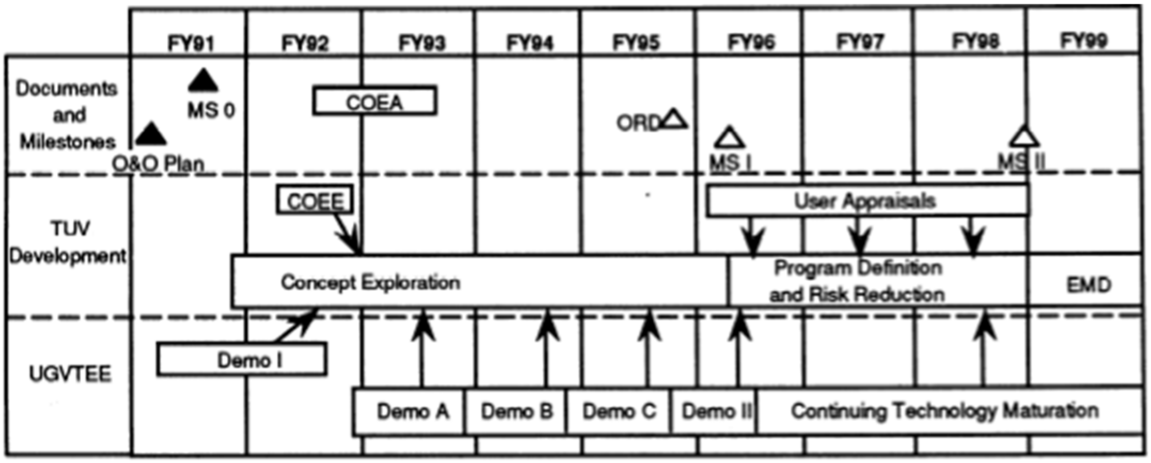
Project	FY00	FY01	FY02	FY03	FY 04	FY05	FY06	FY07
SRS	9.6	7.5	2.0	TBD	0.0	0.0	0.0	0.0
RCSS	3.0	2.7	3.5	TBD	TBD	0.0	0.0	0.0
MPRS	0.5	2.0	2.0	TBD	TBD	TBD	TBD	TBD
MPRS (BUGS)	0.7[a]	0.8	0.9	1.2	1.0	1.5	1.0	1.2
RACS	4.0[b]	3.8	4.2	3.1	2.8	3.1	2.8	2.8
MDARS-I	2.0[c]	2.0	3.0	3.0	0.0	0.0	0.0	0.0
MDARS-E	0.0[c]	2.0	3.0	3.0	0.0	0.0	0.0	0.0
Gladiator	1.0	1.2	1.4[e]	TBD	TBD	TBD	TBD	TBD
JAUGS	0.2	0.6	0.6	TBD	TBD	TBD	TBD	TBD
Intelligent Mobility	3.0	5.2	3.0	2.0	2.0	2.0	2.0	2.0
RAVENS	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Tech Base	8.0	0.0[d]	TBD	TBD	TBD	TBD	TBD	TBD

a. FTUV/Gladiator from 2000 to 2001

As stated earlier, the FTUV program, while no longer represented in the 2001 master plan, has been reduced to one system called the Gladiator, now a named program. "The Gladiator is a teleoperated/semi-autonomous, small to medium sized, highly mobile UGV with, initially, the basic capability to conduct scout/surveillance missions and to carry various mission payloads for specific tasks" (DOD, 2001, p. 21). Essentially, this is a continuation of the FTUV/TUGV program, but on a smaller scale, and with fewer test bed platforms. The document does acknowledge the SARGE and STV systems from the past and how they have led to the development of the Gladiator.

The scout mission still remains a significant challenge for UGVs, and this has plagued the successful delivery of systems at full rate production. The hopes for this system are no different from past systems and will likely challenge the available technology. Ultimately, the Gladiator will do what a Marine can do with the expectation that the Gladiator can operate in day and night conditions across a variety of terrains, including the MOUT environment. The system is expected to conduct target acquisition, breaching, direct fire, reconnaissance, obscuration, counter sniper operations, and serve as a communications relay (DOD, 2001). These are challenging and lofty expectations for any UGV system. Considering this is one of the longest ongoing concepts in the UGV realm, success is not expected at this point in time.

While this is a new program, it is still a spinoff of the FTUV program. There was not an FTUV schedule in the 2000 master plan, so it seemed appropriate to compare the current Gladiator schedule with the last known TUV schedule which was presented in 1996. Figure 95 compares the 1996 TUV schedule with the 2001 Gladiator schedule. If the Gladiator is a continuation of this program, then Milestone II/B has shifted about four years further into the future. Table 26 compares the 1996 TUV funding with the 2000 FTUV funding and 2001 Gladiator funding. The funding for the new program is significantly lower, especially compared to what was programmed in 1996. This may be attributed to the growth in other programs in support of operations in Bosnia, or it could be related to the failure to achieve success in performing the scout mission. The TUV mission, considered the main effort at one point in time, now seems to slip further down the priority list.



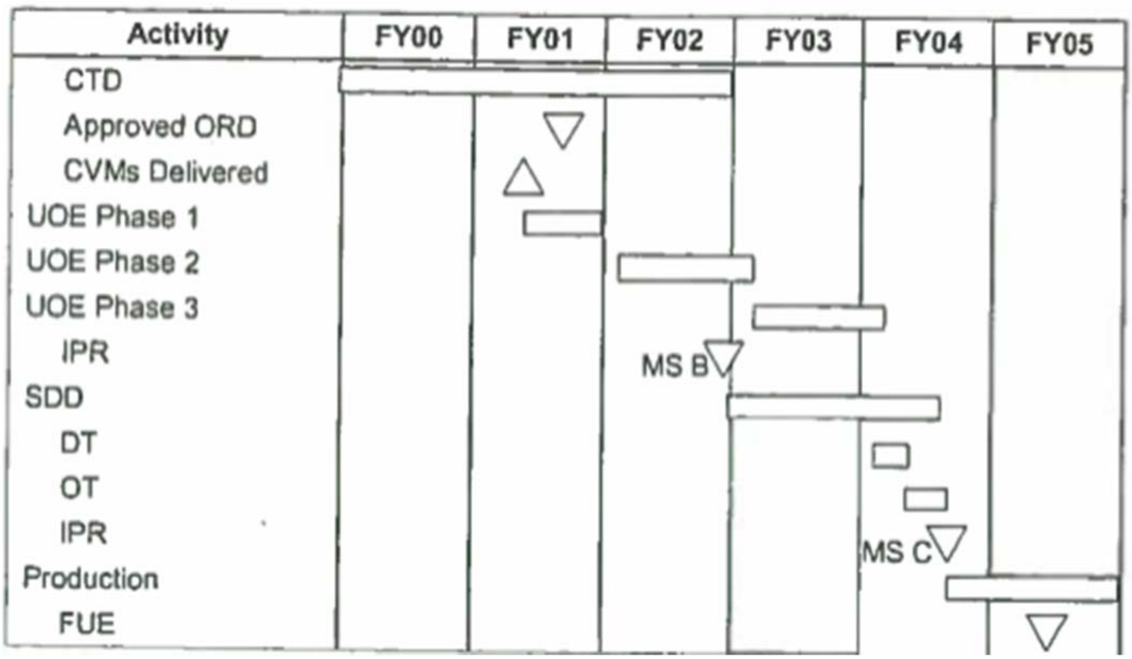


Figure 95. 1996 TUV Schedule Compared to 2001 Gladiator Schedule (from DOD, 1996, 2001)

Table 26. Comparison of 1996 TUV, 2000 FTUV and 2001 Gladiator Funding (from DOD, 1996, 2000, 2001)

ASD Program	FY96	FY97	FY98	FY99	FY00	FY01	FY02
TUV	8.40	8.70	10.30	10.70	11.10	11.00	11.60
VTC	4.00	5.40	4.80	4.80	5.00	5.00	5.00
REVS	2.50	3.50	3.00	3.50	3.50	4.00	4.00
RONS	0.40	0.40	0.40	0.00	0.00	0.00	0.00
Totals	15.30	18.00	18.50	19.00	19.60	20.00	20.60

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	2.0	3.0	5.0	8.0	8.0	11.4	11.8

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	1.0	1.2	1.4	TBD	TBD	TBD	TBD	TBD
Navy	0.0	0.0	5.0	2.5	1.5	0.0	0.0	0.0
Total RDTE	1.0	1.2	6.4	TBD	TBD	TBD	TBD	TBD

b. ROCS/RACS from 2000 to 2001

The 2001 master plan does an excellent job of breaking down this program into distinguishable parts. The JRP master schedule does not display the robotics for agile combat support (RACS) schedule because the program is really four separate systems, each with their own schedule and funding, and all focused on the removal of UXO and defeating IEDs.

> The RACS program is organized in four major activities: (1) development of the ARTS for UXO clearance and neutralization of large terrorist IEDs, (2) development and integration of advanced robotic technologies onto existing platforms, (3) development of an ARC system for explosive ordnance disposal on Air Force ranges, and (4) research and development for the next generation of EOD tools. (DOD, 2001, p. 33)

While there is more detail and a clear breakdown of each system in the 2001 master plan, the schedules presented still do not indicate milestones that are typical of most programs. This has been a consistent theme for this program over the past several years. The JRP master schedule in 2000 did display each system, but the funding for each system was lumped together. The schedule and funding for the 2000 ROCS program is displayed in Figure 60 and Table 10.

Overall, the funding for the RACS program is trending downward in future years, compared to what was planned in the 2000 master plan, but the amount is not very significant. It is not possible to compare system funding at this time, but it is possible in future master plans.

The 2001 RACS schedule and funding does provide greater detail and insight into each system but, the naming convention of events on each system schedule has changed since the 2000 master plan, making it confusing and difficult to track the progress of the overall program and each system. Figure 96 and Table 27 depict the schedule and funding for the all-purpose robotic transport system (ARTS) system. Figure 97 and Table 28 show the schedule and funding for the advanced robotic systems (ARS) systems. Figure 98 and Table 29 present the active range clearance (ARC) system schedule and funding. Lastly, Figure 99 and Table 30 show the schedule and funding for the next generation-force protection robotics system (NG-FPRS) system.

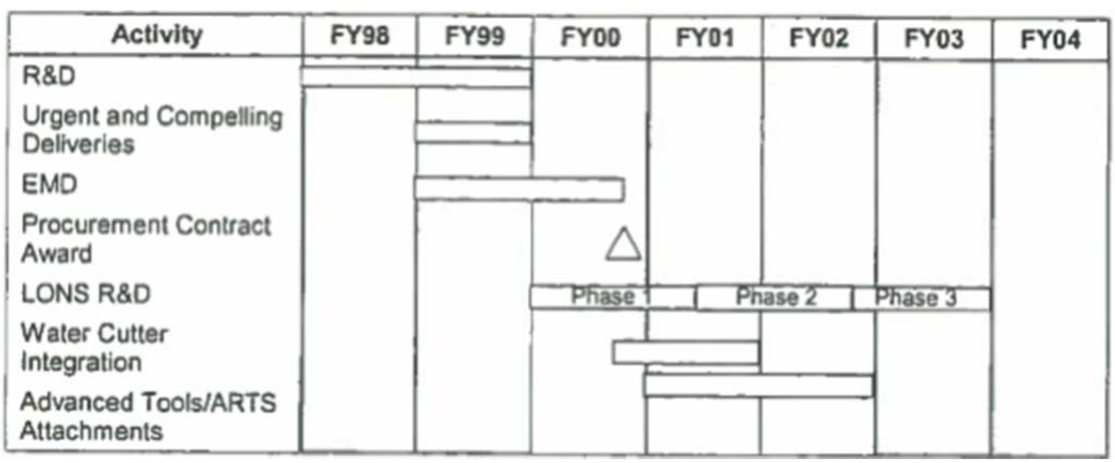


Figure 96. ARTS Schedule 2001 (from DOD, 2001)

Table 27. ARTS Funding 2001 (from DOD, 2001)

Source	FY98	FY99	FY00	FY01	FY02	FY03	FY04
JRP	0.70	0.70	1.00	0.31	1.50	0.50	
Air Force	0.25	0.50	0.60	0.50			
Other[a]	1.00	0.20	0.50	0.25	2.00	2.00	2.00
Total R&D	1.95	1.40	2.10	1.06	3.50	2.50	2.00
AF Procurement	3.00	3.00	5.30	0.75	2.10	3.30	1.70
AF Sustainment		0.50	0.50	0.50	0.50	0.50	0.50
Total	4.95	4.90	7.90	2.31	6.10	6.30	4.20

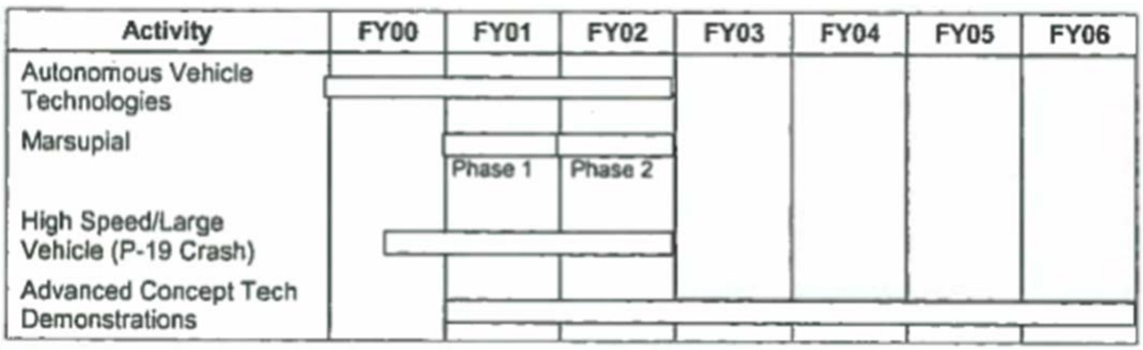


Figure 97. ARS Schedule 2001 (from DOD, 2001)

Table 28. ARS Funding 2001 (from DOD, 2001)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06
JRP	0.8	3.11	2.56	2.14	2.14	2.33	2.61

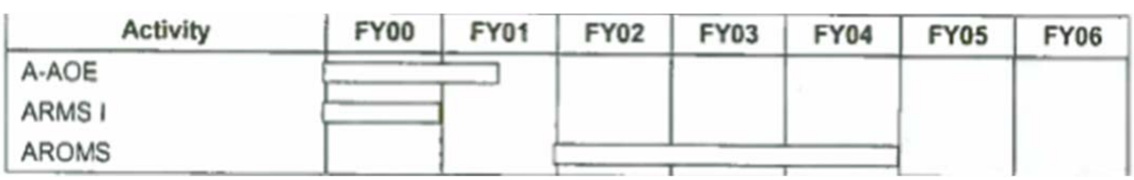


Figure 98. ARC Schedule 2001 (from DOD, 2001)

Table 29. ARC Funding 2001 (from DOD, 2001)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	2.00	1.50					
Air Force		0.30					
Other[a]			0.10	1.00	1.00	1.00	1.00
Total R&D	2.00	1.80	0.10	1.00	1.00	1.00	1.00

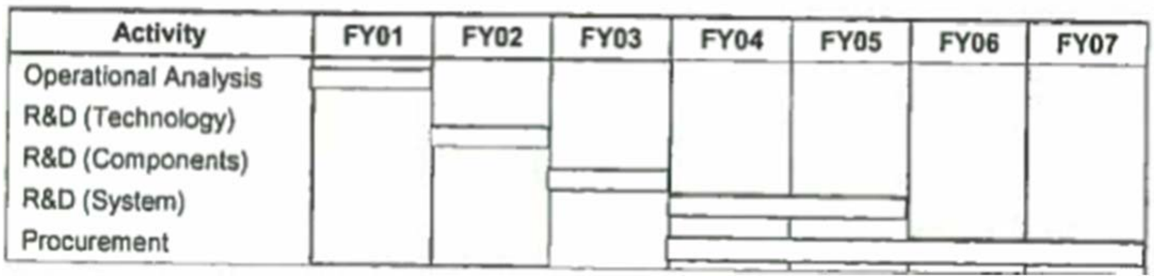


Figure 99. NG-FPRS Schedule 2001 (from DOD, 2001)

Table 30. NG-FPRS Funding 2001 (from DOD, 2001)

Source	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	0.39	0.40	0.40	0.60	0.60		
Air Force	0.20	1.70	1.50	1.30	1.20	0.40	0.40
Other[a]	0.50	2.00	2.00	2.00	2.00	2.00	2.00
Total R&D	1.09	4.10	3.90	3.90	3.80	2.40	2.40
AF Procurement					0.80	0.30	1.20
Other Procurement					5.00	5.00	5.00
Total	1.09	4.10	3.90	3.90	9.60	7.70	8.60

c. VT/SRS from 2000 to 2001

In the past year, the name of the VT program changed to standardized robotic system (SRS). The concept remains the same, vehicles with the SRS applique can be controlled through teleoperation with a remote control from another vehicle or the ability to employ semi-autonomous control if used on a pre-determined path. This program remains the main thrust of the UGV program. Ongoing maintenance and support also continues for M60 and M1 tanks in Bosnia and Kosovo with more Abrams nominated for this upgrade, but the numbers not presented. The SRS has also been installed for operational testing on several engineer vehicles to include the interim vehicle-mounted mine detector (IVMMD), the Meerkat, the mine hunter/killer (MH/K) and an experimental version on the T3 bulldozer (DOD, 2000). The UGVs with SRS, particularly in Bosnia and Kosovo, continue to prove their value as several hundred mines are cited as being neutralized by these systems. Without the direct statement, it is assumed that this technology is greatly appreciated by service members as it removes them from direct harm during detonations.

Figure 100 compares the 2000 VT schedule with the 2001 SRS schedule with Phase 3 of the program extended one year further into the future. Milestone III has shifted one year further to FY02, compared to FY01, in contradiction to what was planned in the 2000 JRPMP. This move also sets back production by one whole year. Table 31 compares the funding of the program from 2000 to 2001 with planned funding for this program reduced from the prior year’s plan. This is either a function of a declining budget or the tapering of the mission in Bosnia and Kosovo.

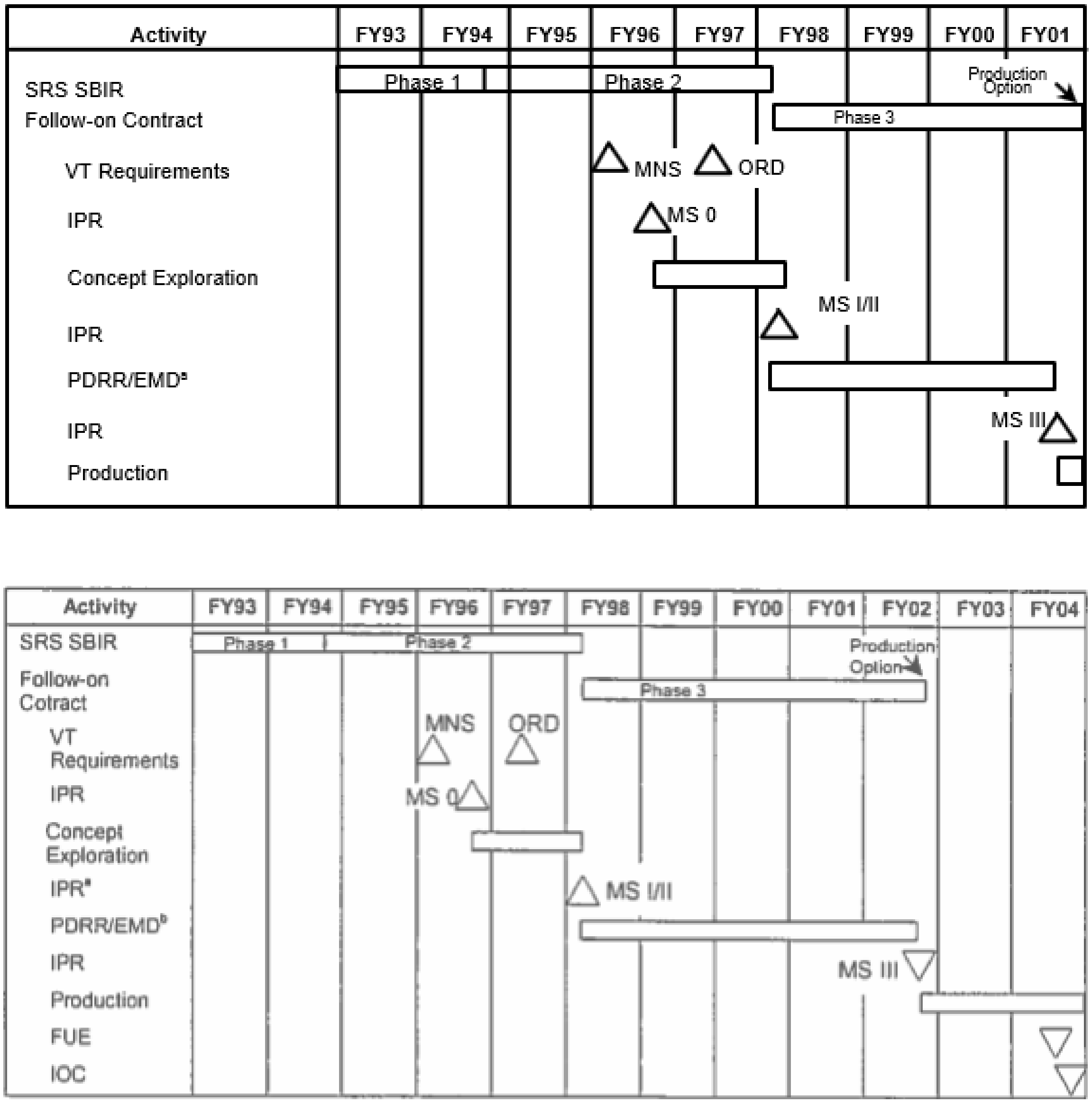


Figure 100. 2000 VT Schedule Comparison to 2001 SRS Schedule (from DOD, 2000, 2001)

Table 31. 2000 VT Funding Compared to 2001 SRS Funding (from DOD, 2000, 2001)

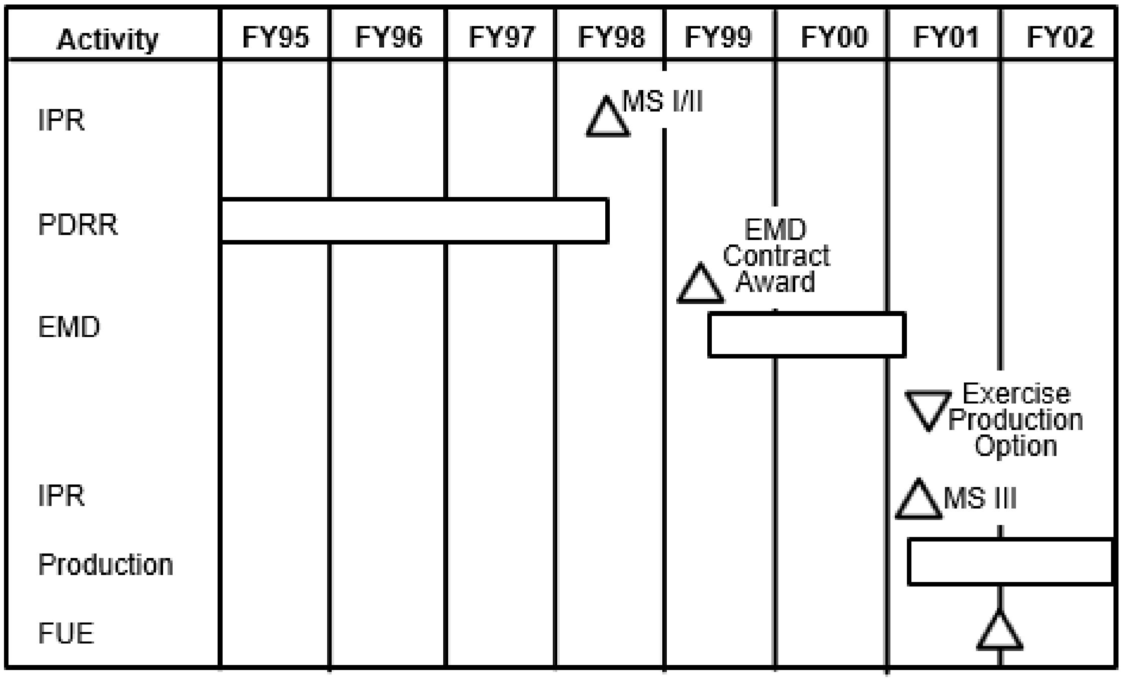
Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	9.7	10.3	3.0	5.0	5.0	5.0	5.0
Army	2.8[a]	0.7[b]					
Total RDT&E	12.5	11.0	3.0	5.0	5.0	5.0	5.0
Procurement	0.0	4.0	0.7	2.4	0.0	0.0	0.0

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	9.6	6.5	2.0	TBD	0.0	0.0	0.0	0.0
Army	0.7[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total RDT&E	10.3	6.5	2.0	TBD	0.0	0.0	0.0	0.0
Procurement	4.0	6.6	2.4	3.0	TBD	TBD	TBD	TBD

d. MDARS-I/E from 2000 to 2001

In the past year, “the MDARS-I pre-production prototype system was fabricated. The MDARS-E completed technical feasibility testing of the full system in a field environment. It also demonstrated technical feasibility of navigation, obstacle avoidance, intrusion detection, product inventory, and lock reading capabilities” (DOD, 2001, pp. 6–7). The technological progress for this program each year was significant, but the schedule is constantly challenged possibly as a result of a declining budget that forces rescheduling or due to the challenges associated with this advanced technology.

Figure 101 compares the MDARS-I schedule from 2000 to the 2001 schedule. Milestone III, which is the marker next to LRIP in the 2001 schedule has slipped from FY01 to FY02 also pushing back the system production. Table 32 compares the funding of MDARS-I from 2000 to 2001; interestingly, the funding increases in all years from what was planned in 2000. The program also receives JRP funding for two more years than previously planned. It also appears that the successful technology demonstrations and systems progression warrants further funding as opposed to eliminating the whole program.



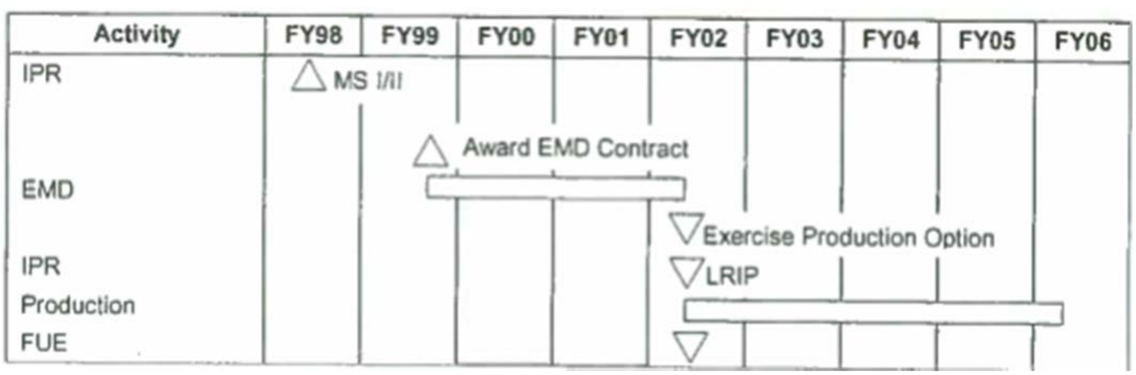


Figure 101. 2000 MDARS-I Schedule Compared to 2001 MDARS-I Schedule (from DOD, 2000, 2001)

Table 32. 2000 MDARS-I Funding Compared to 2001 MDARS-I Funding (from DOD, 2000, 2001)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	3.1	1.7	1.5				
PSE	0.0	0.0	0.0	3.3	2.2	2.2	2.2
RDT&E Total	3.1	1.7	1.5	3.3	2.2	2.2	2.2

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	3.1	1.7	1.5				
PSE	0.0	0.0	0.0	3.3	2.2	2.2	2.2
RDT&E Total	3.1	1.7	1.5	3.3	2.2	2.2	2.2

Figure 102 compares the 2000 MDARS-E schedule with the 2001 MDARS-E schedule. For just a one-year span, the schedule slippage is significant. Milestone I/II shifts one year into the future along with the EMD contract award and the EMD time period doubles from what was planned a year earlier. Most significant is the three-year shift further in time of Milestone III which was planned for FY02 in the 2000 JRPMP to FY05 in the 2001 JRPMP. Table 33, however, compares the funding for MDARS-E from 2000 to 2001 and indicates that the program funding actually increases and also receives one more year of JRP funding from what was planned a year earlier.

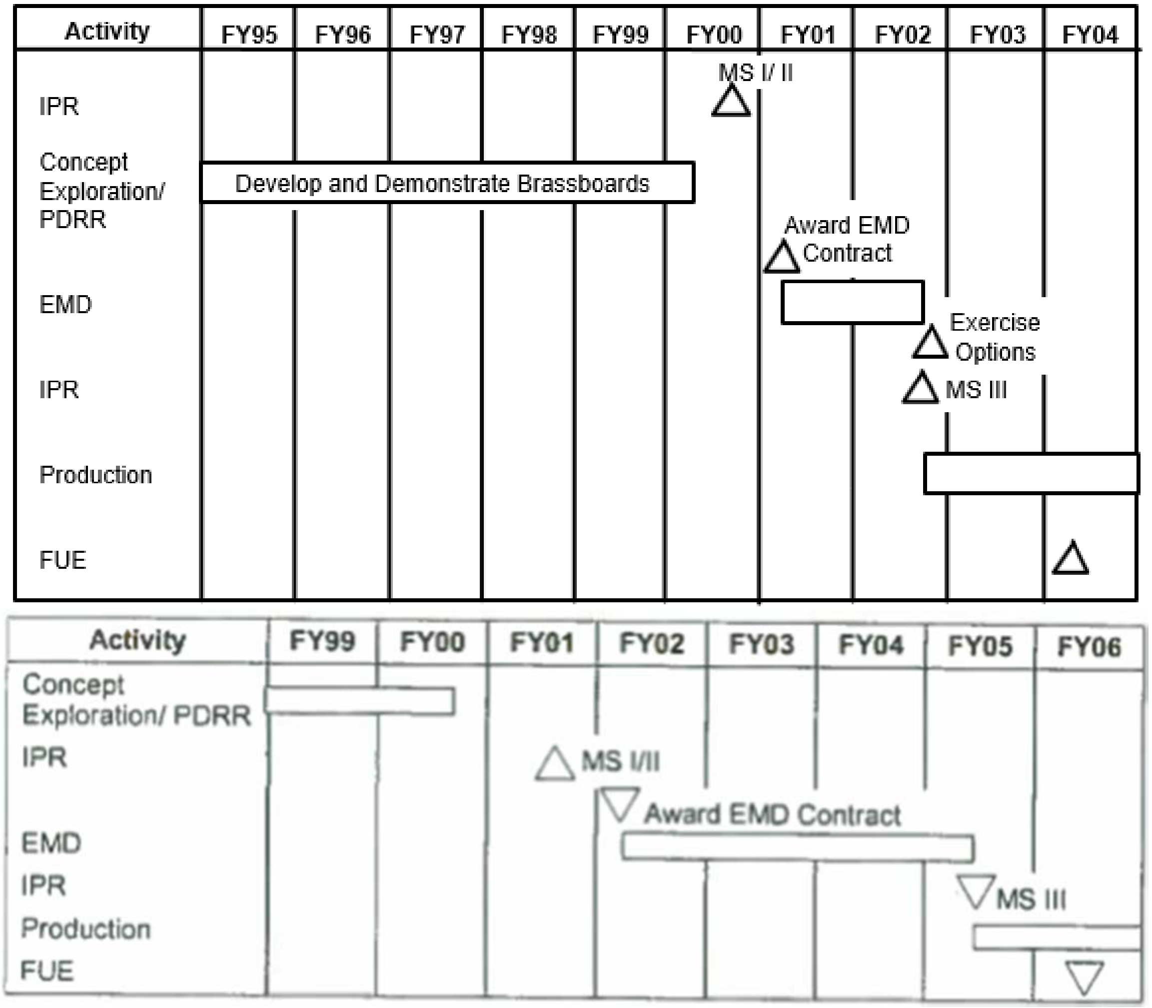


Figure 102. 2000 MDARS-E Schedule Compared to 2001 MDARS-E Schedule (from DOD, 2000, 2001)

Table 33. 2000 MDARS-E Funding Compared to 2001 MDARS-E Funding (from DOD, 2000, 2001)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	0.0	0.0	1.0	3.0	0.0	0.0	0.0
PSE	5.5	4.9	5.6	0.0	3.7	4.4	4.4
RDT&E Total	5.5	4.9	6.6	3.0	3.7	4.4	4.4

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	0.0	2.0	3.0	3.0	0.0	0.0	0.0	0.0
PSE	3.9	2.5	0.0	0.0	0.0	0.0	0.0	0.0
RDT&E Total	3.9	4.5	3.0	3.0	0.0	0.0	0.0	0.0

e. BUGS from 2000 to 2001

The 2001 JRPMP does a great job of explaining the BUGS program in greater detail, and it also presents some tangible results in autonomous operation for UGVs. Essentially there are two BUGS systems in development. The simpler of the two versions was produced and tested by the Navy to conduct random searches. One operator remains at a control unit and sends out seven vehicles to search randomly and autonomously within a given boundary, while avoiding obstacles and other vehicles. If a UXO is discovered, the system brings the UXO to a designated location.

The second version of the system, produced by a contractor, is called a designated search system and is considered to be the more complicated version. Much like the Navy version, this system requires one operator at a control unit to deploy up to five vehicles to conduct autonomous clearance of a prescribed area. The key difference is that these robots build a dynamic UXO map of the searched area.

While the robots do conduct autonomous operations, this can only exist in a structured environment. As the 2001 JRPMP states, "Full autonomy is the goal; truly autonomous robots operating purposefully in unstructured environments currently do not exist" (DOD, 2001, p. 31). Full autonomy is still very challenging, even after 10 years working on this technology. Even so, the fact that this technology has been successfully demonstrated is a large achievement and the results of this will carry forward to many other programs in a useful manner.

Much like the other programs in this year, the schedule for BUGS shifts further than was planned the year prior. Figure 103 compares the 2000 schedule with the 2001 BUGS schedule. In all other programs, the milestones were depicted as I, II, and III. This is also the first time that milestones are seen as letters. In the 2001 plan, Milestone A is planned for FY03 instead of FY02. Milestone B has shifted almost two years into the future from FY04 to FY06. Table 34 compares the funding from 2000 to 2001 and the overall program funding trends downward in future years compared to what was planned in 2000. Funding increases in FY01, but is down in all other years thereafter.

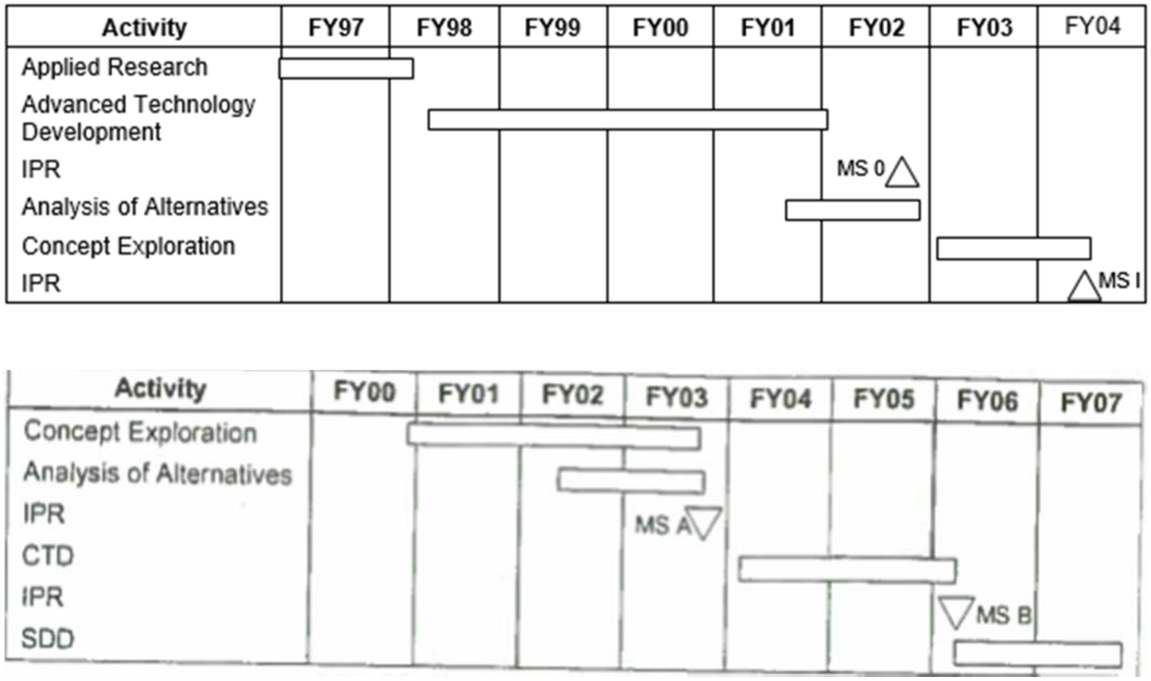


Figure 103. 2000 BUGS Schedule Compared to 2001 BUGS Schedule (from DOD, 2000, 2001)

Table 34. 2000 BUGS Funding Compared to 2001 BUGS Funding (from DOD, 2000, 2001)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	0.7	0.7	0.7	1.0	2.0	2.0	2.0
Navy			0.2	0.9	1.0	1.1	1.1

	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	0.7	0.8	0.9	1.2	1.0	1.5	1.0	1.2
Navy	0.4	0.6	0.5	0.8	1.2	1.0	1.5	1.5
Total RDTE	1.1	1.5	1.4	2.0	2.2	2.5	2.5	2.7

f. RCSS from 2000 to 2001

According to the 2001 JRPMP, the use of the mini-flail in the program's success led to requirements that now exceed the system's capabilities. "RCSS will replace the mini-flail's anti-personnel (AP) mine neutralization capability and will also be capable of accepting other mission modules" (DOD, 2001, p. 4). Not much else is reported on this program in the past year. With the decision to produce a needed system to meet emerging requirements, a significant shift in the program schedule occurs.

Figure 104 compares the RCSS schedule from 2000 to the 2001 RCSS schedule. Milestone A has shifted one year further into the future compared to what was planned last year. Milestones B, C, and production have all shifted two years further than what was planned in the 2000 JRPMP. The funding comparison of RCSS between 2000 and 2001 is shown in Table 35. Overall funding has also been cut by about 50% and with no planned funding projected beyond FY02.

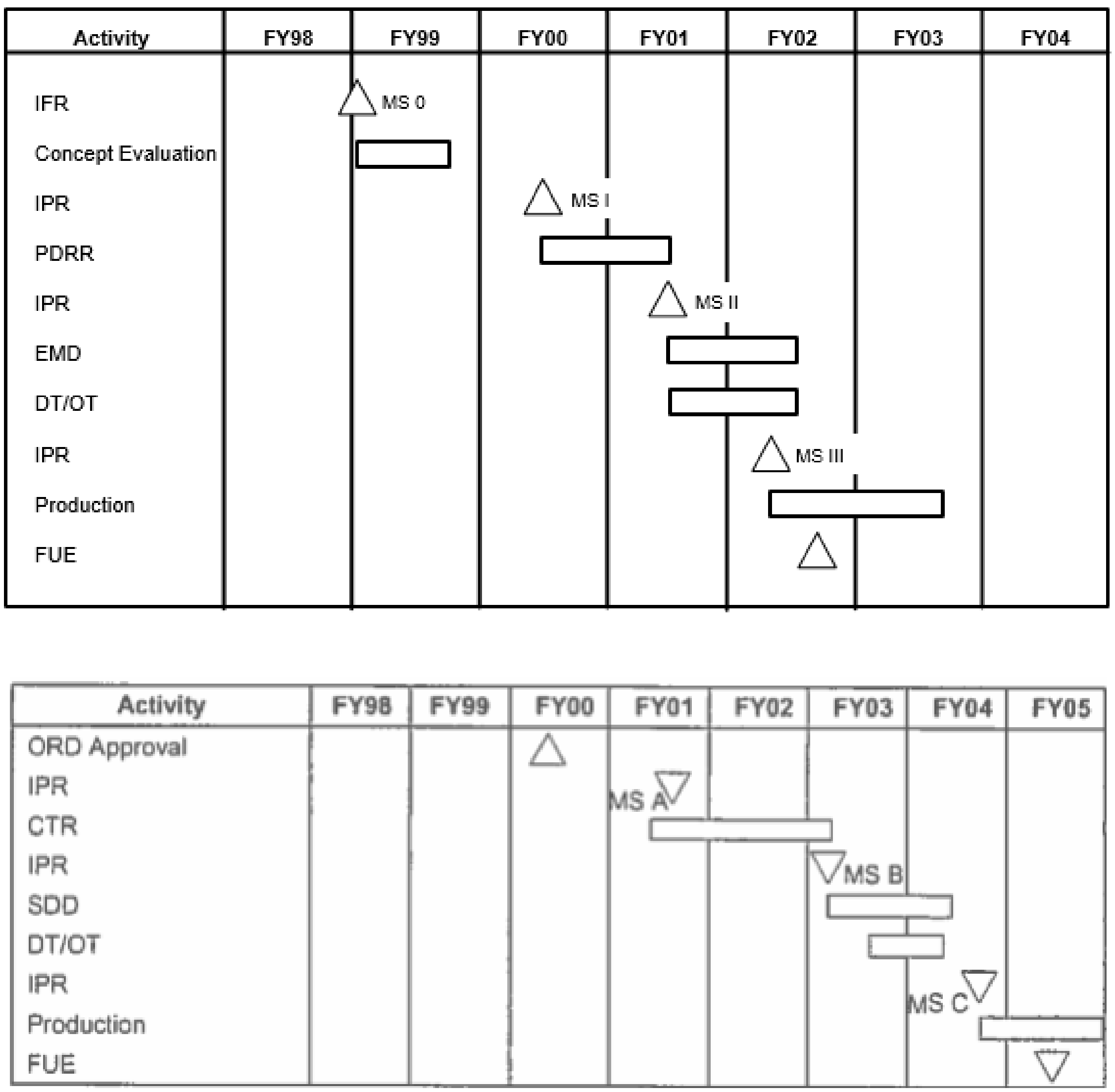


Figure 104. 2000 RCSS Schedule Compared to 2001 RCSS Schedule (from DOD, 2000, 2001)

Table 35. 2000 RCSS Funding Compared to 2001 RCSS Funding (from DOD, 2000, 2001)

Source	FY99	FY00	FY01	FY02	FY03	FY04	FY05
JRP	1.9	3.0	6.1	3.2	3.0	0.0	0.0
Army	1.4[a]	0.6[b]	0.0	0.0	0.0	0.0	0.0
Total RDT&E	3.3	3.6	6.1	3.2	3.0	0.0	0.0
Procurement	0.0	0.0	0.0	4.7	2.1	0.0	0.0

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	3.0	2.7	3.5	TBD	TBD	TBD	0.0	0.0
Army	0.6[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total RDT&E	3.6	2.7	3.5	TBD	TBD	TBD	0.0	0.0
Procurement	0.0	0.0	0.0	4.1	3.5	TBD	TBD	TBD

g. MPRS 2001

Man-portable robotic systems (MPRS) is one of the new programs in the 2001 JRPMP. The document states that

> there is a rapidly growing interest in small, man-portable robotic systems to perform a variety of tasks that are high risk to humans. These include tasks associated with MOUT (e.g., building clearing, tunnel and sewer reconnaissance and under vehicle inspection), and EOD operations. (DOD, 2001, p. 23)

There are two systems under the MPRS program, in a sub-program called light-weight equipment reconnaissance system (LERS); URBOT and Matilda. These systems are intended to be carried individually by one Soldier, or disassembled by two Soldiers. They are expected to provide 4–12 hours of continuous operations and be semi-autonomous (DOD, 2001). Both systems carry a host of cameras and sensors to give users visibility about what is going on at the site of investigation.

The URBOT depicted in Figure 105 is a tracked vehicle with an OCU that the operator can wear as a backpack. It has a wire and control pendant coming from the pack that allows the operator to control the robot when within visible range. One key note is that the URBOT employs software architecture from the MDARS and JAUGS program.

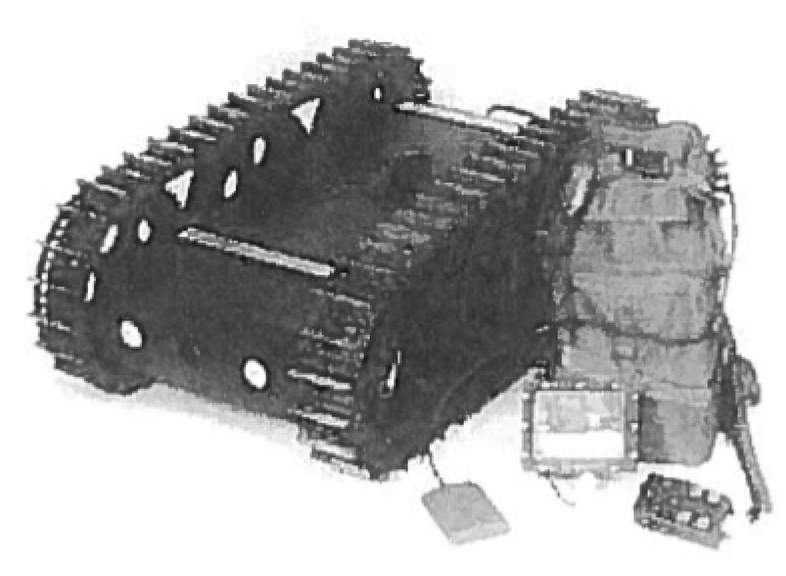


Figure 105. Picture of the URBOT System (from DOD, 2001)

The Matilda system depicted in Figure 106 is also a tracked UGV with planned uses in an urban environment (inside and outside) and in field environments. “The system provides users with reconnaissance, surveillance, and under-vehicle inspection capabilities. The platform is also capable of carrying a variety of payloads and tools” (DOD, 2001, p. 25). The vehicle is controlled with an OCU that is stored in a case and requires the use of a joystick.

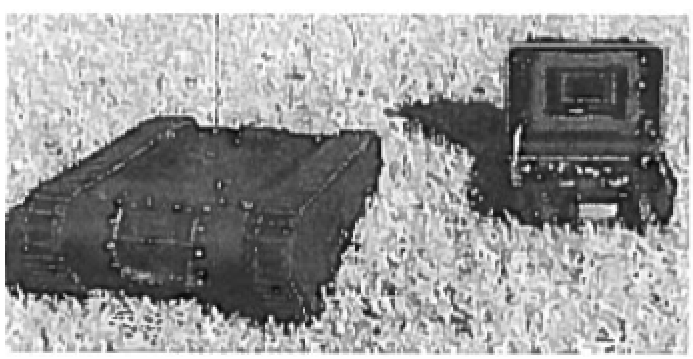


Figure 106. Picture of the Matilda System (from DOD, 2001)

Figure 107 depicts the first LERS schedule with a time line of six years to achieve Milestone C. While certainly attainable, it is based on past performances of other programs, with a schedule expected to slip further to the right over the next few years. The first round of funding for the MPRS program is shown in Table 36. Only three years of funding are planned at this time. The funding also appears to be relatively significant considering the size of the systems and the fact that they are using technology developed by other programs.

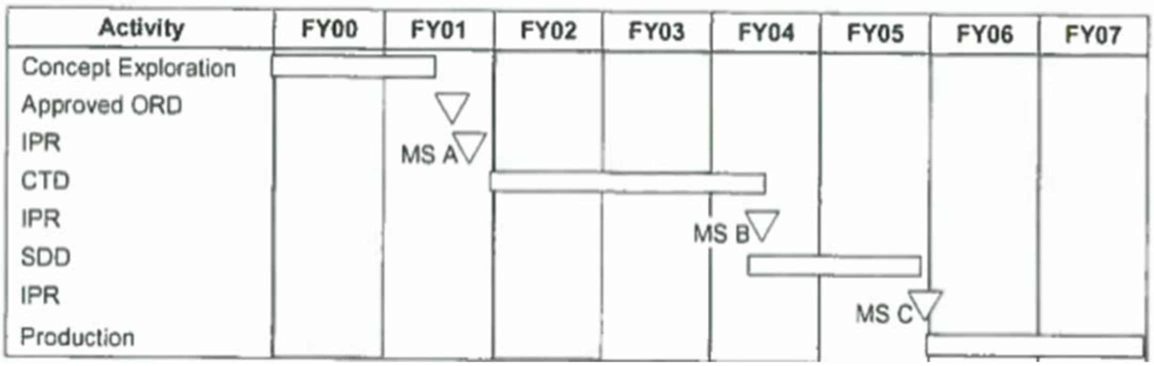


Figure 107. LERS Schedule 2001 (from DOD, 2001)

Table 36. MPRS Funding 2001 (from DOD, 2001)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	0.5	2.0	2.0	TBD	TBD	TBD	TBD	TBD

h. RAVENS 2001

Robotic acquisition through virtual environments and networked simulations (RAVENS) is another new program in the 2001 JRPMP. In the most basic terms, RAVENS allow stakeholders to log onto a computer and participate in collaborative events to promote shared understanding of various UGV programs. "RAVENS provides members of the JRP, users, and developmental and operational test centers with a robust environment to conduct tests, experiments and analyses using a 'stay at home' concept" (DOD, 2001, p. 53). Figure 108 displays a theoretical model used to explain the concept of RAVENS. Figure 109 is a graphic that gives the reader an idea of what it is like to be logged into the RAVENS portal during a collaborative event. The funding for RAVENS is depicted in Table 37, as the overall funding table for all 2001 UGV programs.

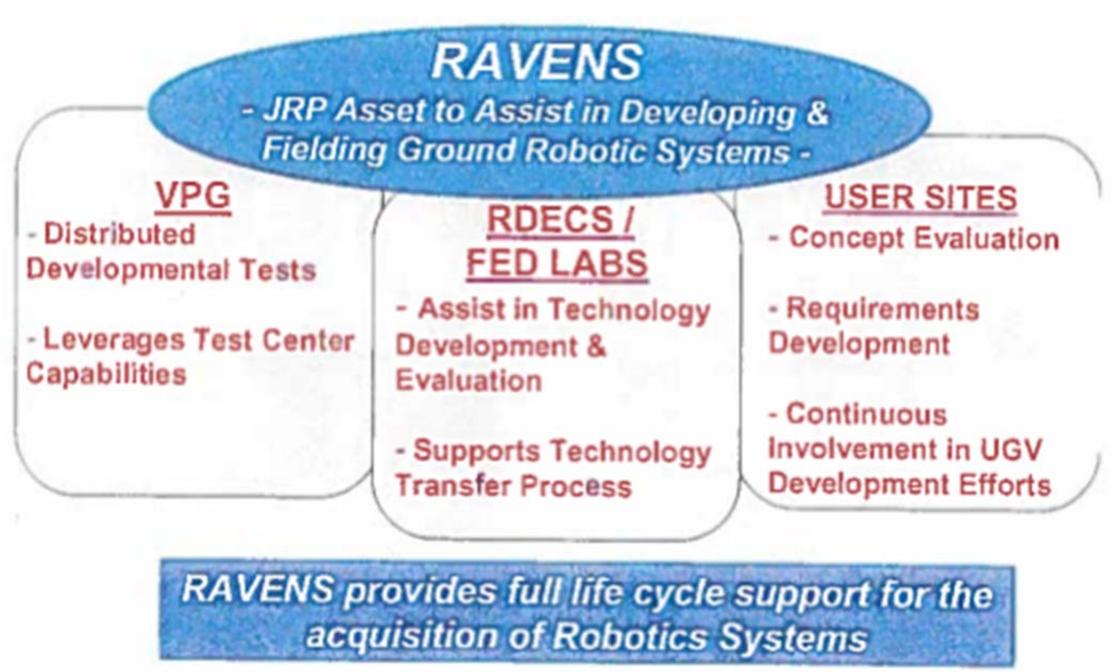


Figure 108. Model of the RAVENS Program 2001 (from DOD, 2001)

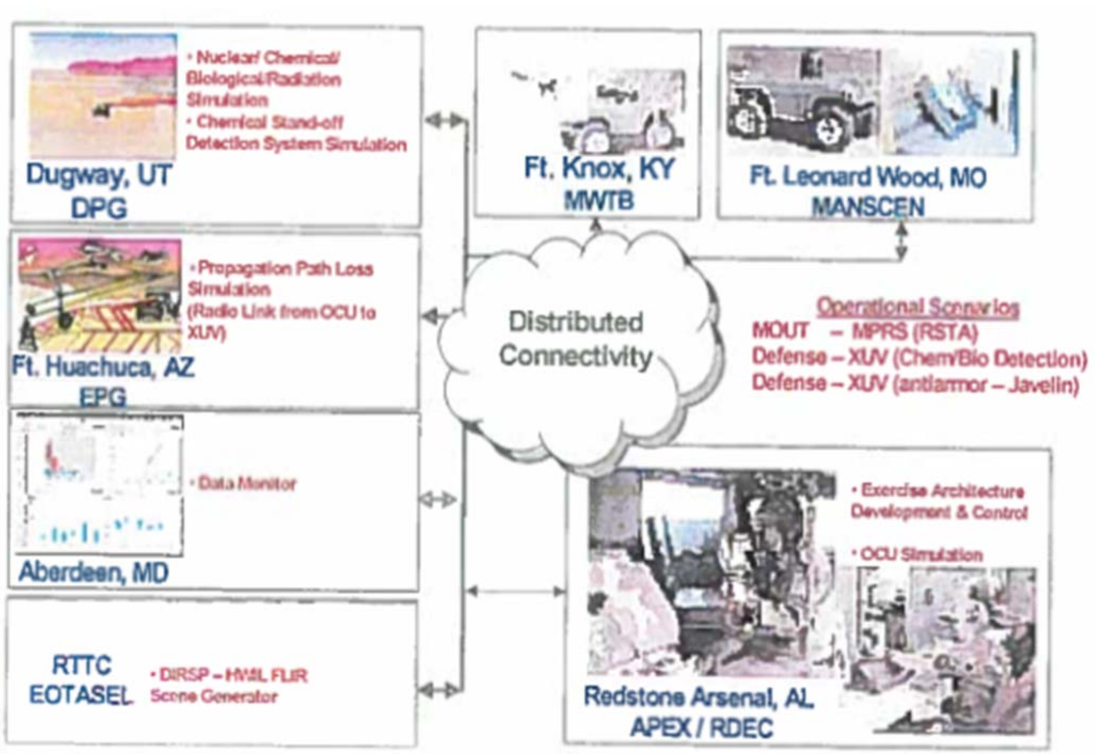


Figure 109. Graphical Depiction of RAVENS Concept (from DOD, 2001)

Table 37. RAVENS Funding 2001 (from DOD, 2001)

Project	FY00	FY01	FY02	FY03	FY 04	FY05	FY06	FY07
SRS	9.6	7.5	2.0	TBD	0.0	0.0	0.0	0.0
RCSS	3.0	2.7	3.5	TBD	TBD	0.0	0.0	0.0
MPRS	0.5	2.0	2.0	TBD	TBD	TBD	TBD	TBD
MPRS (BUGS)	0.7[a]	0.8	0.9	1.2	1.0	1.5	1.0	1.2
RACS	4.0[b]	3.8	4.2	3.1	2.8	3.1	2.8	2.8
MDARS-I	2.0[c]	2.0	3.0	3.0	0.0	0.0	0.0	0.0
MDARS-E	0.0[c]	2.0	3.0	3.0	0.0	0.0	0.0	0.0
Gladiator	1.0	1.2	1.4[e]	TBD	TBD	TBD	TBD	TBD
JAUGS	0.2	0.6	0.6	TBD	TBD	TBD	TBD	TBD
Intelligent Mobility	3.0	5.2	3.0	2.0	2.0	2.0	2.0	2.0
RAVENS	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Tech Base	8.0	0.0[d]	TBD	TBD	TBD	TBD	TBD	TBD

i. Intelligent Mobility Program 2001

The intelligent mobility program is another new program in 2001 and it seems to have the closest relationship to DEMO III with perhaps a small remnant of that program. "The primary objective is to improve the intrinsic and operational mobility of UGVs through the development and demonstration of novel running gear configurations using intelligent control systems and artificial intelligence" (DOD, 2001, p. 49). The ultimate goal of this program is to improve UGVs ability to traverse off-road terrain. This program consists of two systems: the T3 vehicle and the omnidirectional inspection system (ODIS).

As a test platform, the T3 is essentially different hardware components and software applications that can be plugged into the vehicle and played with to record the results and make corrections. Successful combinations can be used on other UGV platforms to see the effects and results.

The ODIS's primary purpose is to maintain a low profile and inspect under vehicles. This system has a military and civil application, particularly with police departments. Agencies or corporations where security is vital may also be good candidates for this technology.

There is no schedule for this program in the 2001 JRPMP, but there is a funding table which is displayed in Table 38. Funding for this program is planned for no less than $2 million in any year and is planned out through FY07. This is a significant amount of funding and the time frame is far off enough that significant results are expected.

Table 38. IMP Funding 2001 (from DOD, 2001)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	3.0	5.2	3.0	2.0	2.0	2.0	2.0	2.0

j. JAUGS 2001

The JAUGS program was visible in previous master plans and there was a one-year schedule for the JAUGS program in 1995. This is a JRP initiative to develop architecture for the UGV domain. "It is component-based, message-passing architecture that specifies data formats and methods of communicating among computer nodes" (DOD, 2001, p. 49). The goal of JAUGS is to ensure that there is open architecture in the UGV program. Each new technology must adhere to the Joint Technical Architecture for the long-run financial and technical benefit of the program. The JAUGS program does not have a schedule in the 2001 JRPMP but the funding table is depicted in Table 39. Funding is planned for threes at this point in time. The second version of the JAUGS standards was published in 2000 and more versions are expected as long as the program continues.

Table 39. JAUGS Funding 2001 (from DOD, 2001)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	0.2	0.6	0.6	TBD	TBD	TBD	TBD	TBD

k. RONS 2001

The last time RONS appeared in a master plan was in 1996 when it was on schedule to achieve Milestone III in early FY99 and initial operational capability (IOC) in late FY99. The 2001 JRPMP gives an update on RONS and shows that the program achieved Milestone III in 1999 and began full rate production. The system was deployed in support of operations in Kosovo for use by EOD personnel. The number of systems that have already been delivered to each service and the number of systems planned for each service is shown in Table 40. Table 41 depicts the RONS procurement funding by service and year. Figure 110 is a picture of what the system and control unit look like after production.

Table 40. RONS Systems Delivered and Planned 2001 (from DOD, 2001)

2001	Army	Navy	Air Force	Marines	Totals
Delivered	49	28	30	0	107
Planned	49	28	84	11	172
Objective	98	56	114	11	279

Table 41. RONS Procurement Funding by FY (from DOD, 2001)

Service	FY			
	99	00	01	02
Army	2.178	3.740	0.600	
Marine Corps				4.100
Navy	1.568	1.568		
Air Force	0.900	2.100	0.900	
Total	4.646	7.408	1.500	4.100

Figure 110. Picture of a Full Rate Production RONS System (from Project Manager Close Combat Systems, n.d.)

Overall, this is a success story for UGV programs. This is the only one of two programs so far that has attained full rate production. The program appears to be on track for continued success and is likely the program to inspire the PackBot and Talon robots. In this master plan, the RONS system is called the MK 2 MOD 0 which is similar to the naming convention that the PackBot and Talon fall under today.

2. 2003 Joint Robotics Program Master Plan

During the data collection portion of this project, no document was found that covers the UGV program during the year 2002. The document may have been written, but it is not located with any agencies, where the other documents were collected. The 2003 JRPMP is an interesting document because it has many new events to consider in conjunction with the program. The military continues to conduct operations in the Balkans and is engaged in the war on terror in Afghanistan and Iraq. The FCS program is directly mentioned in the document and plays a large role in several system programs and the overall direction of the UGV program. The requirements that led to the solution for that year is shown in Table 42.

Table 42. Requirements Articulation 2003 Joint Robotics Master Plan

2003
Requirement
Breaching
Countermine Operations
Develop & Field family of UGVS for range of military applications IAW user requirements
Environmental Cleanup
Explosive Ordnance Disposal
Firefighting, handling & loading of aircraft munitions, multiple UXO during clearing operations
Logistics
Military Operations in Urban Terrain (MOUT)
Minefield Detection & Neutralization
NBC Detection and Laser Designation
Obstacle Detection
Physical Security
Reconnaissance, Surveillance, and Target Acquisition (RSTA)
Remote Mine Clearance
Small, lightweight, man-portable UGV to be used for Recon urban environment & other terrain (Infantry/Armor)
TUGV - Supporting the Infantry
UXO
Threat/Conflict
9/11/2001 (9/11 Attacks)
Afghanistan - Operation Enduring Freedom (OEF-A)
Iraq - Operation Iraqi Freedom (OIF) (2003-2012)
Continued peacekeeping operations in the Balkins (Bosnia & Kosovo)
UGV Solution
Family of Tactical Unmanned Vehicles (FTUV) renamed Gladiator Reconnaissance, Surveillance, and Target Acquisition (RSTA) small to medium sized, highly mobile UGV with capability to conduct scout suveillance missions and to carry various mission payloads for a specific task.
Robotic Ordnance Clearing System (ROCS) Runway Repair (fix holes, remove debris,safe removal of personnel and hazardous areas) - All-Purpose Robotic Transport System (ARTS) - clear paths on ranges or minefields (ARTS-FP)- clearance of large UXO or potential IEDs - Active Range Ordnance Mapping System (AROMS) - Automated Ordnance Excavator (AOE) (1996)
Remote Ordnance Neutralization System(RONS)(Initiated 1990)(renamed from Remote Ordnance Neutralization Device (ROND) Explosive Ordnance Disposal
Basic UXO Gathering System (BUGS) (initiated 2000) (RONS+FUTV+REVS) Part of the RONS program salvaged and merged with parts from the REVS and TUV to create BUGS man-portable, EOD support UGV.
Mobile Detection Assessment Response System - Interior/Exterior (MDARS-I/E) (Initiated 1992) Reduce manpower by patrolling exterior of buildings and compounds in day, night, hot, cold, wet & dry conditions Added security inside military facilities such as large warehouses and depots
Vehicle Teleoperation (VT) Program renamed Standardized Robotic System (SRS) Remote Mine Clearance Breaching Environmental Cleanup
Joint Architecture for Unmanned Ground Systems (JAUGS) (Initiated 1995) Develop common hardware/software open achitecture to ensure intraoperability (vehicle to vehicle) Interoperability (data communications in command, control, communications, computers & intel (C4I) result in cost savings
Robotic Combat Support System (RCSS) (initiated 2000) (REVS + VT)
Unmanned Ground Vehicle Technology Enhancement and Exploitation (UGVTEE) DEMO III CANCELED
Man-Portable Robotic System (MPRS) (initiated 2001) Tasks associated with MOUT (e.g., building clearing, tunnel and sewer rceconaissance, under vehicle inspection, and EOD operations. - Light-Weight Equipment Reconnaissance System (LERS); URBOT and Matilda
Robotic Acquisition through Virtual Environments & Networked Simulations (RAVENS) (initiated 2001) Stakeholders can log onto a computer and participate in collaborative events
Intelligent Mobility Program (initiated 2001) Improve UGVs ability to travers off-road terrain - T3 Vehicle & Omnidirectional Inspection System (ODIS)

In FY03, Congress appropriated an additional $24 million in funding to the UGV program to "expeditiously test, produce, and field technologically mature robots and other unmanned vehicles for use in combat" (DOD, 2003, p. 10). The use of UGVs in the war on terror by service members has resulted in positive feedback and increased demand for more systems. The systems offer Soldiers the ability to search areas, conduct reconnaissance, and neutralize IEDs with standoff that significantly reduces risk.

In the past few years, the UGV portfolio has grown significantly. Most of the 11 programs reported in the 2001 JRPMP still remain in place and there are more new programs, bringing the total number to 13 programs in 2003. Another portion is likely related to the success of UGV programs like RONS and ARTS which are in full rate production and in the hands of end users. The demand for more systems is expected as more and more UGV systems are seen and utilized by warfighter users.

In the latest master plan, the UGVs have been broken down by weight class. The classes include: small (light), small (medium), small (heavy), and large. Figure 111 is a graphic depiction of each system in the UGV program, separated by appropriate weight class.

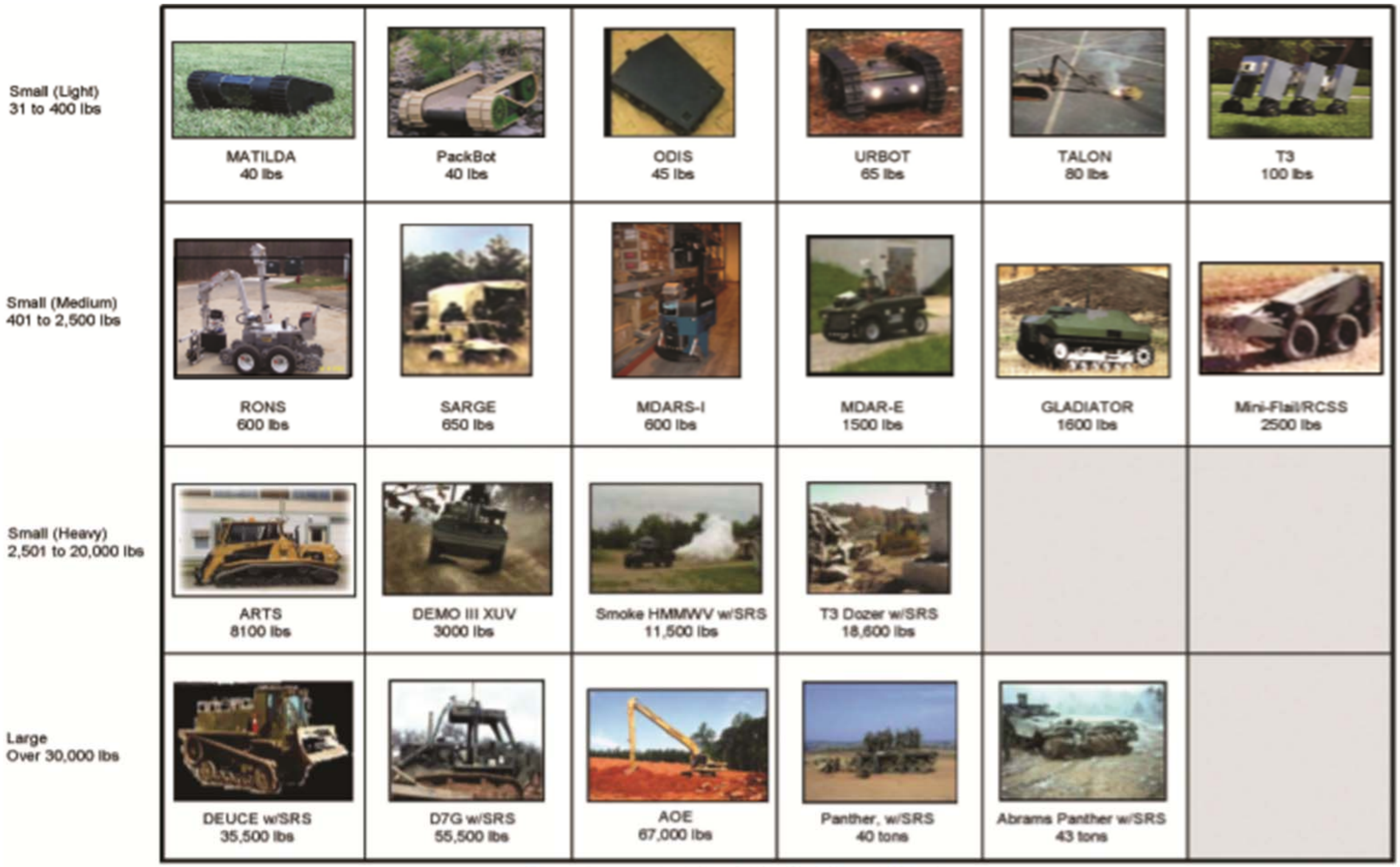


Figure 111. UGV Program Systems by Weight Class 2003 (from DOD, 2003)

Figure 112 compares the 2001 JRP Master Milestone Schedule with the 2003 JRP Master Milestone Schedule. Five of the programs that were active in 2001 have slipped further into the future than what was planned earlier. The MDARS-I program Milestone C has been moved ahead of schedule by two years. The combined operations battlefield robotics asset (COBRA) Milestone B moved ahead by one year but its Milestone C slipped right by one year. The RONS and ARTS systems are still in full rate production and all signs point to the program transitioning to sustainment. Six programs reveal their schedules for the first time, including JAUS, which was mentioned in 2000, but no schedule was presented. Table 43 compares the overall UGV program funding from 2001 to 2003. All programs that were represented in the 2001 JRPMP see greater funding in FY02 compared to what was planned in 2001. For most programs listed in 2001, there was no planned funding for FY03. The funding that was planned for FY03 for MDARS-E in 2001 has doubled and the RONS procurement funding has tripled. A new trend observed in this master plan is that funding for all programs is only listed for the year prior and the current year. A future years defense plan (FYDP) is not presented for any programs. There is no explanation for this change, but it may be possible that funding switch from program objective memorandum (POM) funding to supplemental funding.

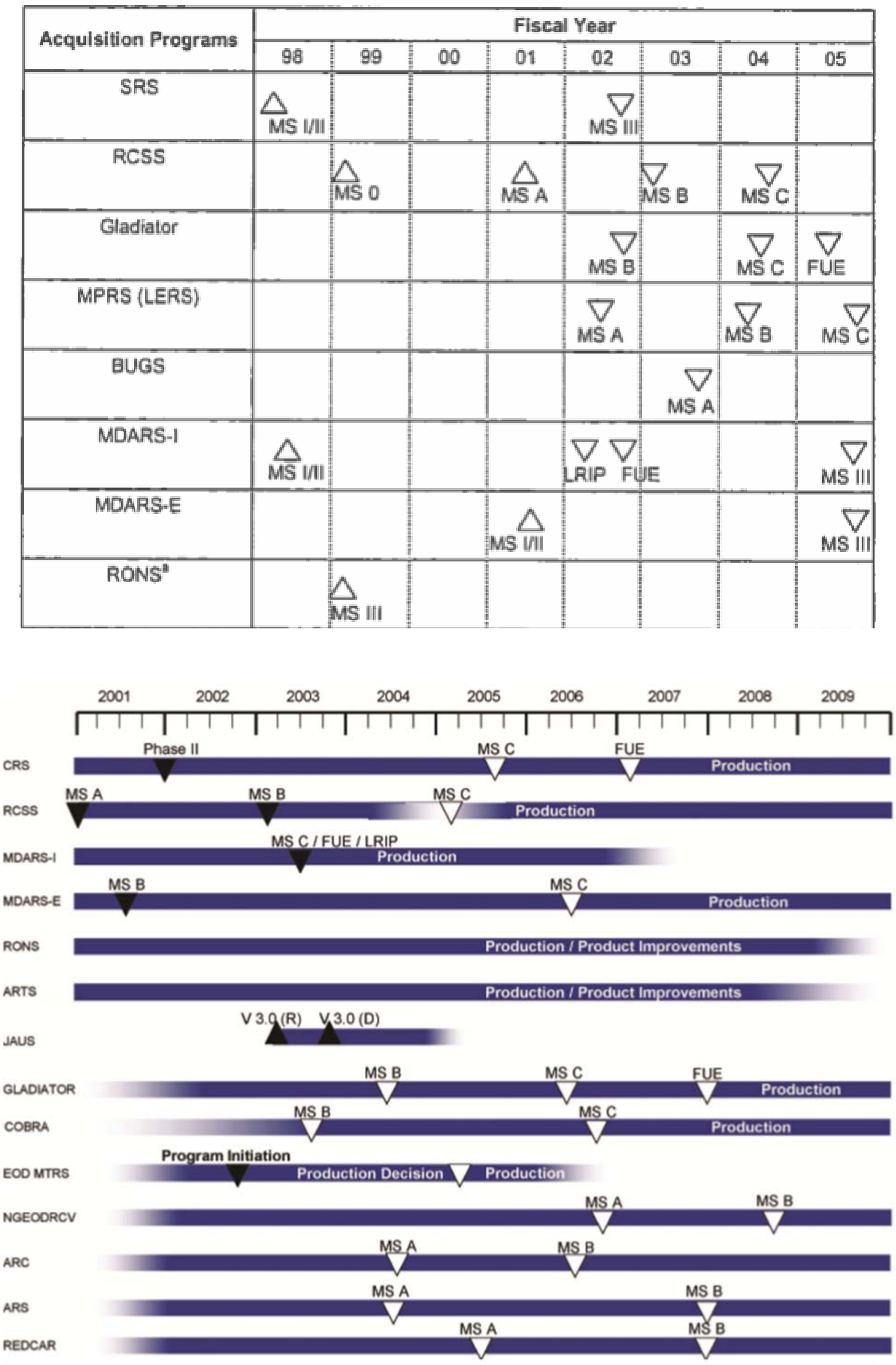


Figure 112. 2001 UGV Master Schedule Compared to 2003 UGV Master Schedule (from DOD, 2001, 2003)

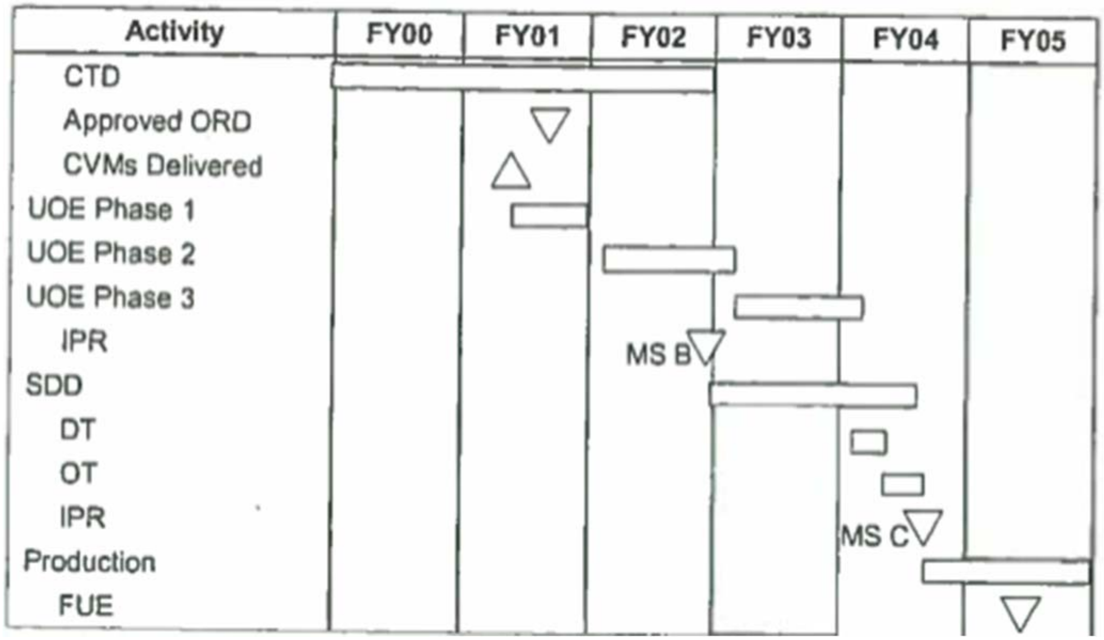
Table 43. 2001 UGV Program Funding Compared to 2003 UGV Program Funding (from DOD, 2001, 2003)

Project	FY00	FY01	FY02	FY03	FY 04	FY05	FY06	FY07
SRS	9.6	7.5	2.0	TBD	0.0	0.0	0.0	0.0
RCSS	3.0	2.7	3.5	TBD	TBD	0.0	0.0	0.0
MPRS	0.5	2.0	2.0	TBD	TBD	TBD	TBD	TBD
MPRS (BUGS)	0.7[a]	0.8	0.9	1.2	1.0	1.5	1.0	1.2
RACS	4.0[b]	3.8	4.2	3.1	2.8	3.1	2.8	2.8
MDARS-I	2.0[c]	2.0	3.0	3.0	0.0	0.0	0.0	0.0
MDARS-E	0.0[c]	2.0	3.0	3.0	0.0	0.0	0.0	0.0
Gladiator	1.0	1.2	1.4[e]	TBD	TBD	TBD	TBD	TBD
JAUGS	0.2	0.6	0.6	TBD	TBD	TBD	TBD	TBD
Intelligent Mobility	3.0	5.2	3.0	2.0	2.0	2.0	2.0	2.0
RAVENS	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Tech Base	8.0	0.0[d]	TBD	TBD	TBD	TBD	TBD	TBD

PROJECT	FY02	FY03
RACS	4.3	2.5a
JAUS	0.8	0.8
MDARS-E	3.7	8.9
MDARS-I	3.4	2.9
CRS	3.6	8.8
GLADIATOR		2.9
RCSS	4.3	5.7
EOD MTRS	0.3	1.0
COBRA	3.5	2.6
JT SVC EOD (RONS)	0.8	2.1
TARDEC	1.0	2.9
Tech Base	0.0[b]	1.0
SPAWAR	–	4.0

a. Gladiator from 2001 to 2003

The Gladiator is the USMC tactical unmanned vehicle (TUV) of choice and is a system that has evolved from lessons learned in the SARGE and STV system programs. The USMC believes that robotic technology has matured enough that this system can make significant contributions to the force. While the force may have a desire to utilize this system, the overall robotic reconnaissance program has not yielded any fully fielded systems. This program has been in existence since the first master plan and systems continually change as schedules push further to the right. Figure 113 compares the 2001 Gladiator schedule with the 2003 Gladiator schedule. In two years, the schedule has slipped significantly. The Milestones B and C decisions that were planned in 2001 have now shifted about one-and-a-half years further into the future in the new plan. FY03 funding for this program was not planned in 2001, but there is $2.9 million of JRP funding for this system in 2003.



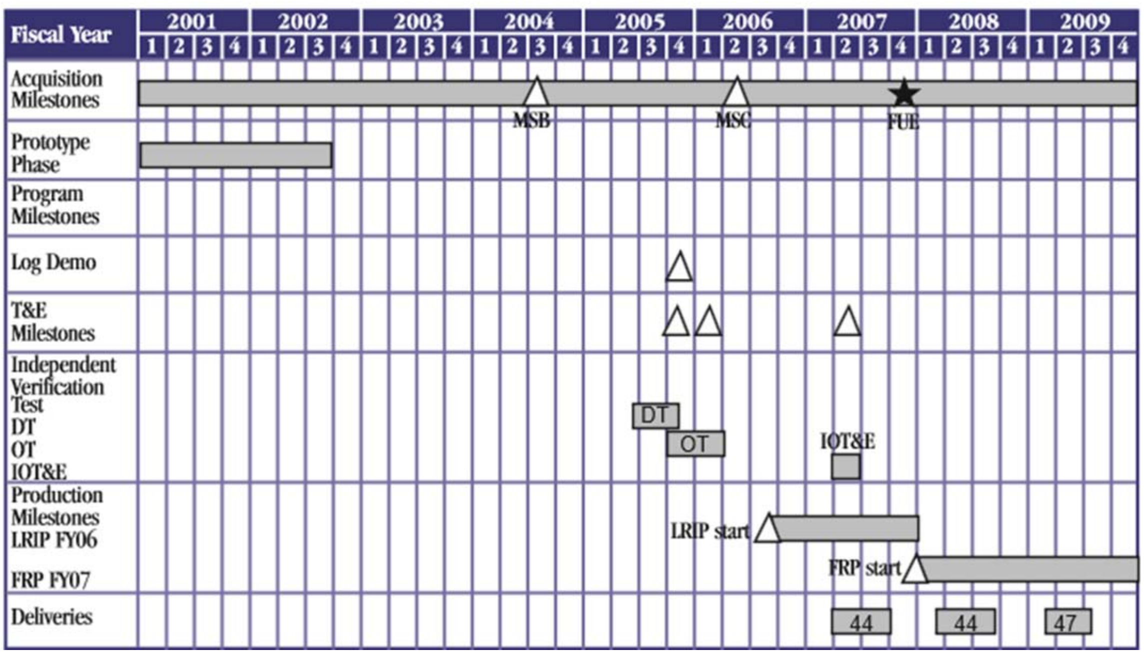


Figure 113. 2001 Gladiator Schedule Compared to 2003 Gladiator Schedule (from DOD, 2001, 2003)

b. RACS from 2001 to 2003

In the 2003 JRPMP, the robotics for agile combat support (RACS) program consists of four systems, each presented individually. The systems include ARTS, ARS, ARC, and remote detection, challenge, and response system (REDCAR). The all-purpose robotic transport system (ARTS) program is a carryover from previous master plans and this program is in full rate production. Through FY02, 42 operational ARTS have been fielded and there are another two systems that are designated for test purposes. There is a contract in place to acquire 20 more ARTS systems (DOD, 2003). Figure 114 depicts a schedule for all components of the program. Each component has its own milestones to achieve and there are a total of eight ongoing improvements in this schedule. The ARTS procurement that was planned in 2001 has increased in the 2003 plan. The ARTS program also consumes about 70% of the total RACS funding each year.

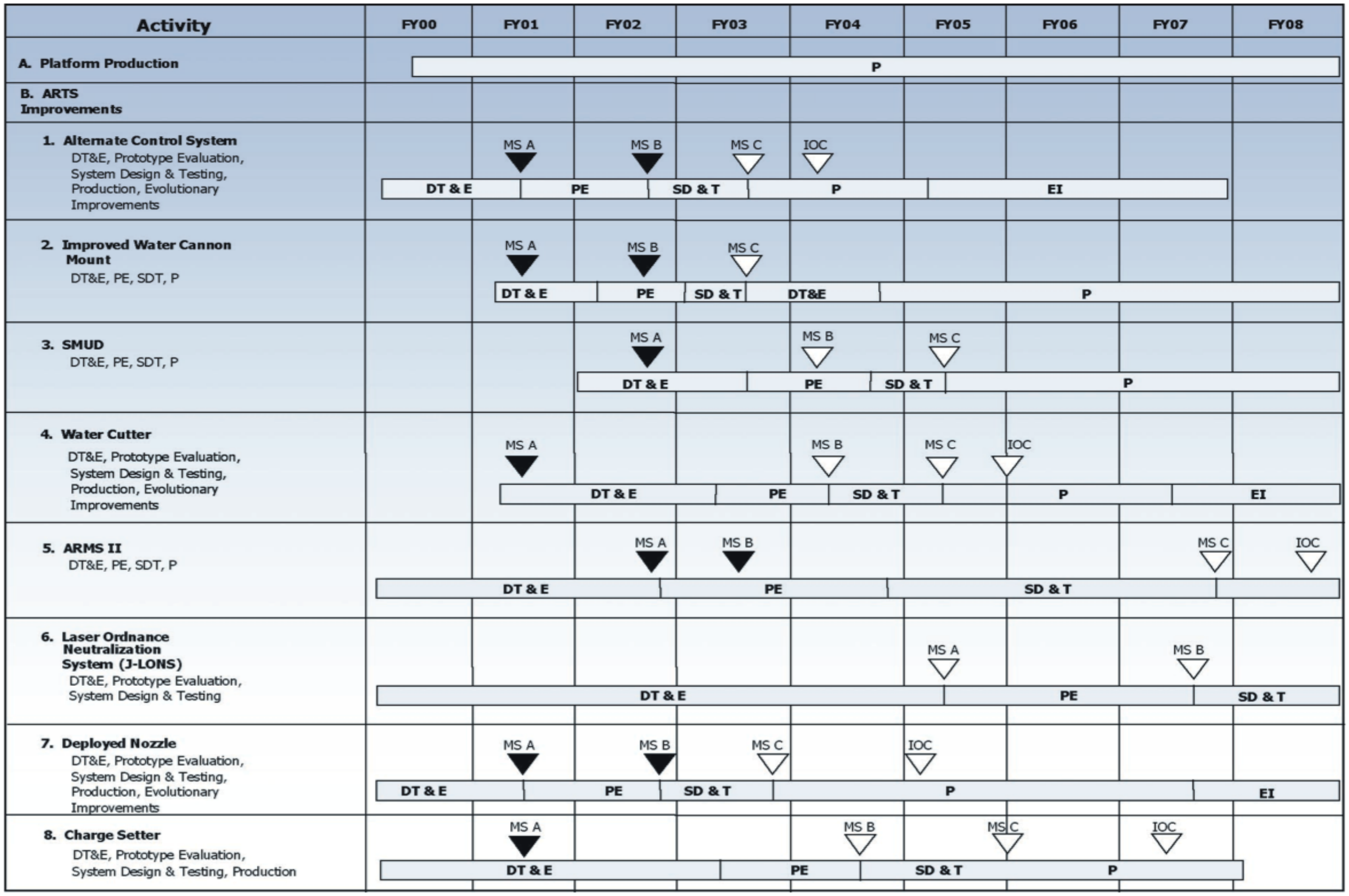


Figure 114. ARTS Program Schedule 2003 (from DOD, 2003)

The active range clearance (ARC) is the second system program under the RACS program. This is also a carryover from the 2001 master plan and it was referred to as advanced ordnance excavator (AOE). The ARC is a program that has been in development for many years. It is basically a Caterpillar brand excavator that is designed to travel a target area, locate deep buried ordnance, dig up and move the ordnance to a safe location while the operator observes at a safe distance. "The development path for this technology is a four-step process: (1) automated digging; (2) independent boom/stick motion; (3) independent machine mobility, and (4) independent work planning and analysis" (DOD, 2003, p. 100). The fact that this development has been ongoing for so many years raises concern. It appears that this task is presented as a simple matter, but the technology is not mature enough to sufficiently complete the mission. Figure 115 compares the 2001 ARC schedule with the 2003 ARC schedule. The 2003 schedule has Milestone A planned for 2004 and Milestone B in 2006. The funding for this program is challenging to pinpoint. In the 2001 master plan, there was specific funding for the AOE program, but the 2003 plan only shows RACS funding and ARTS funding. It is known that ARTS consumes about 70% of the program funds so the other 30% is shared between the ARC, ARS and REDCAR programs. The researchers' assumption is that each program receives an equal share of about 10%.

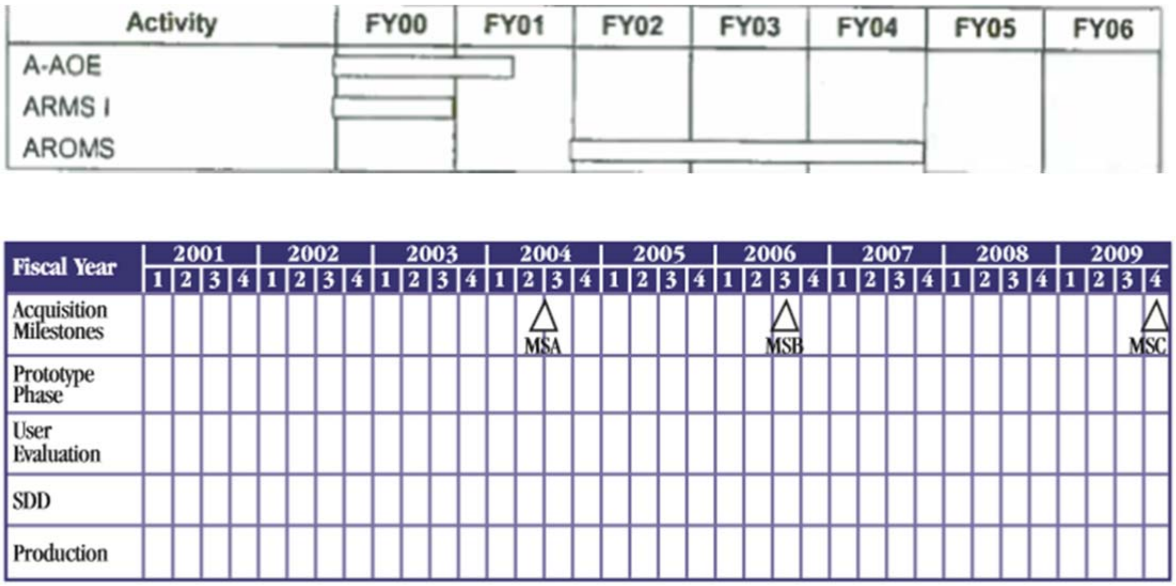


Figure 115. 2001 ARC Schedule Compared to 2003 ARC Schedule (from DOD, 2001, 2003)

The advanced robotic system (ARS) is a program under RACS that was presented in the 2001 master plan. In the 2001 plan, this system was not explained very well but the 2003 master plan does a good job of closing this gap. The primary effort of the ARS is to "develop common architecture designs for autonomous vehicle technologies that focus on vehicle mobility, speed, and control, as well as multi-vehicle operations and marsupial control" (DOD, 2003, p. 109). Based upon the language used in this document, it appears that the BUGS program, which was in the 2001 plan but not the 2003 plan, has been transferred into this program. "The Marsupial Control effort serves to extend the sensing and manipulation capabilities beyond what the larger vehicle can accomplish. Systems such as MATILDA, ANDROS, TALON, Mark VI, URBOT and other remotely operated platforms are being integrated onto the ARTS" (DOD, 2003, p. 110). Figure 116 presents a big picture overview of the Marsupial Control concept which basically allows one larger UGV to transport and control several smaller UGVs in a prescribed area. The 2001 ARS schedule was not as developed as the 2003 schedule. Figure 117 compares the two schedules and the updated schedule now presents milestones; Milestone A is planned for 2004 and Milestone B at the very end of 2007. Again, the funding for this program is unknown, much like the ARC program funding.

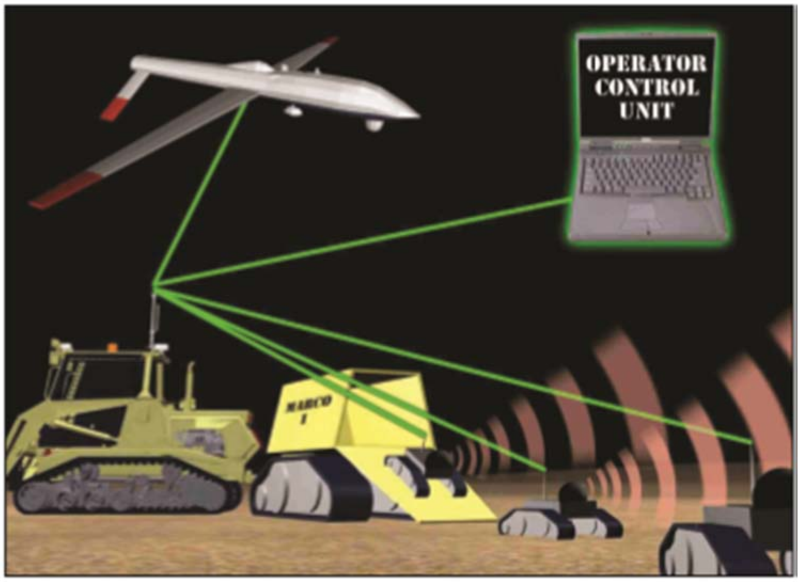


Figure 116. Marsupial Concept 2003 (from DOD, 2003)

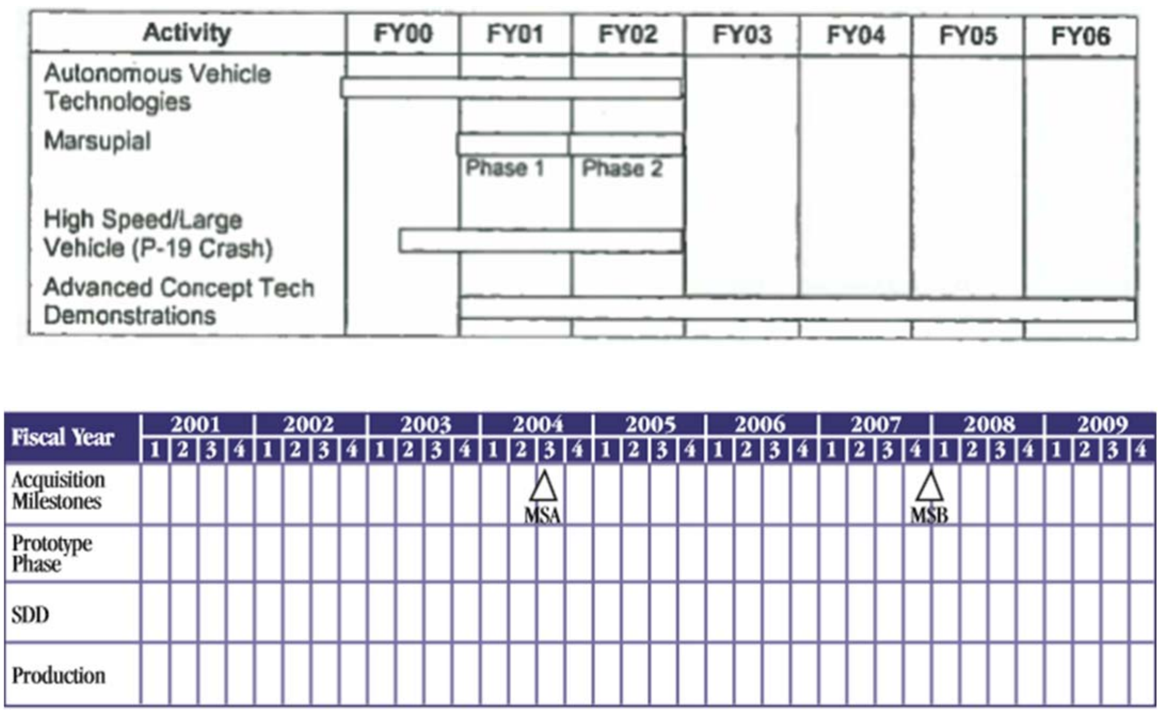


Figure 117. 2001 ARS Schedule with 2003 ARS Schedule (from DOD, 2001, 2003)

In 2003, the remote detection, challenge, and response system (REDCAR) program is the latest edition to the RACS program. This is an Air Force program aimed at utilizing UGVs for force protection instead of humans. This program has characteristics similar to the MDARS-I/E program and the document states that technology is being shared with this program and the Gladiator program. “REDCAR will use at least three different robotic platforms: (1) a surveillance platform; (2) an engagement platform, and (3) a small-scale platform for limited access areas” (DOD, 2003, p. 105). This program seeks to augment or replace security personnel on Air Force installations and with units that may be forward deployed. The MDARS program appears to be successfully accomplishing the security task associated with the program, but the schedule does slip regularly. The REDCAR program should be able to achieve technical success, but the schedule and funding will likely be the challenge for this program. One other challenge will be with the engagement portion of the system as leaders are unlikely to give up decision making authority to a system at this point in time. Figure 118 is the first REDCAR schedule; Milestone A is planned for FY05 and Milestone B for FY07.

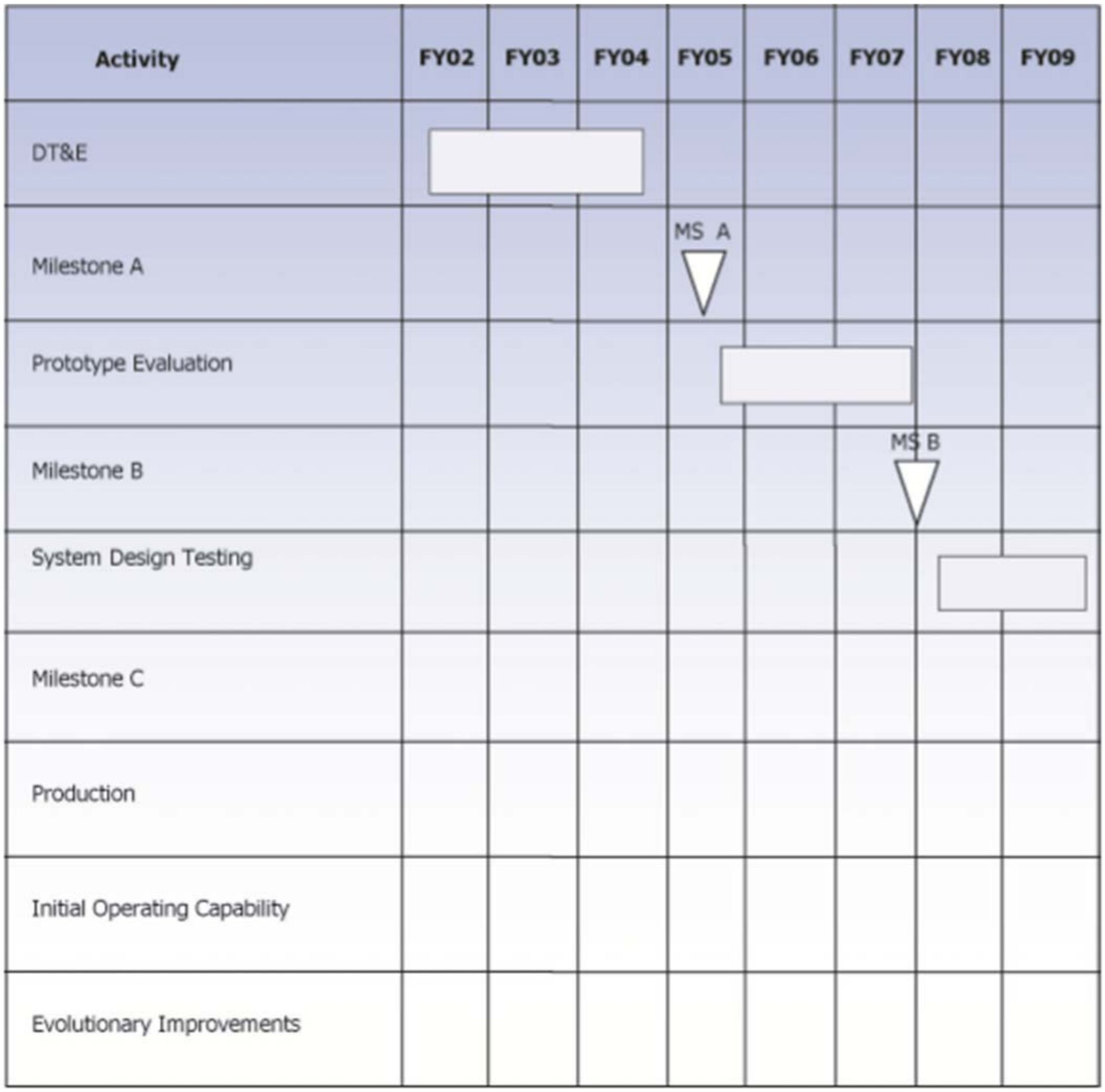


Figure 118. REDCAR Program Schedule 2003 (from DOD, 2003)

c. *SRS/CRS from 2001 to 2003*

The SRS program name was changed to common robotic system (CRS) since the last JRPMP in 2001. The document states that the name change was executed to better align with and reflect the program's acquisition strategy. This acquisition strategy is not presented, but the name has changed multiple times for this program, and perhaps this does offer an explanation to the numerous name changes in all UGV programs. The master plan does state that common robotic kits (CRKs) will be fielded and developed, but this is not a huge change from the word standardized associated with SRS. In the past two years, all M60 Panther systems that were operational in Bosnia and Kosovo have been replaced by M1 Panther systems (DOD, 2003). Figure 119 compares the schedule between SRS in 2001 and CRS in 2003. A large slip can be seen in the schedule for Milestone C, from a planned date in late 2002 to late 2005. This is a two-and-a-half-year change to the schedule. Table 44 presents the funding comparison of the program between the 2001 and 2003 JPRMP. The JPR funding that was planned in 2001 has increased significantly in 2001, almost 100%; previously, Army funding was not planned for this program beyond FY00, but now Army funding for FY02 and FY03 is seen. The schedule appears to slip further to the right and the funding continues to increase before full rate production is achieved.

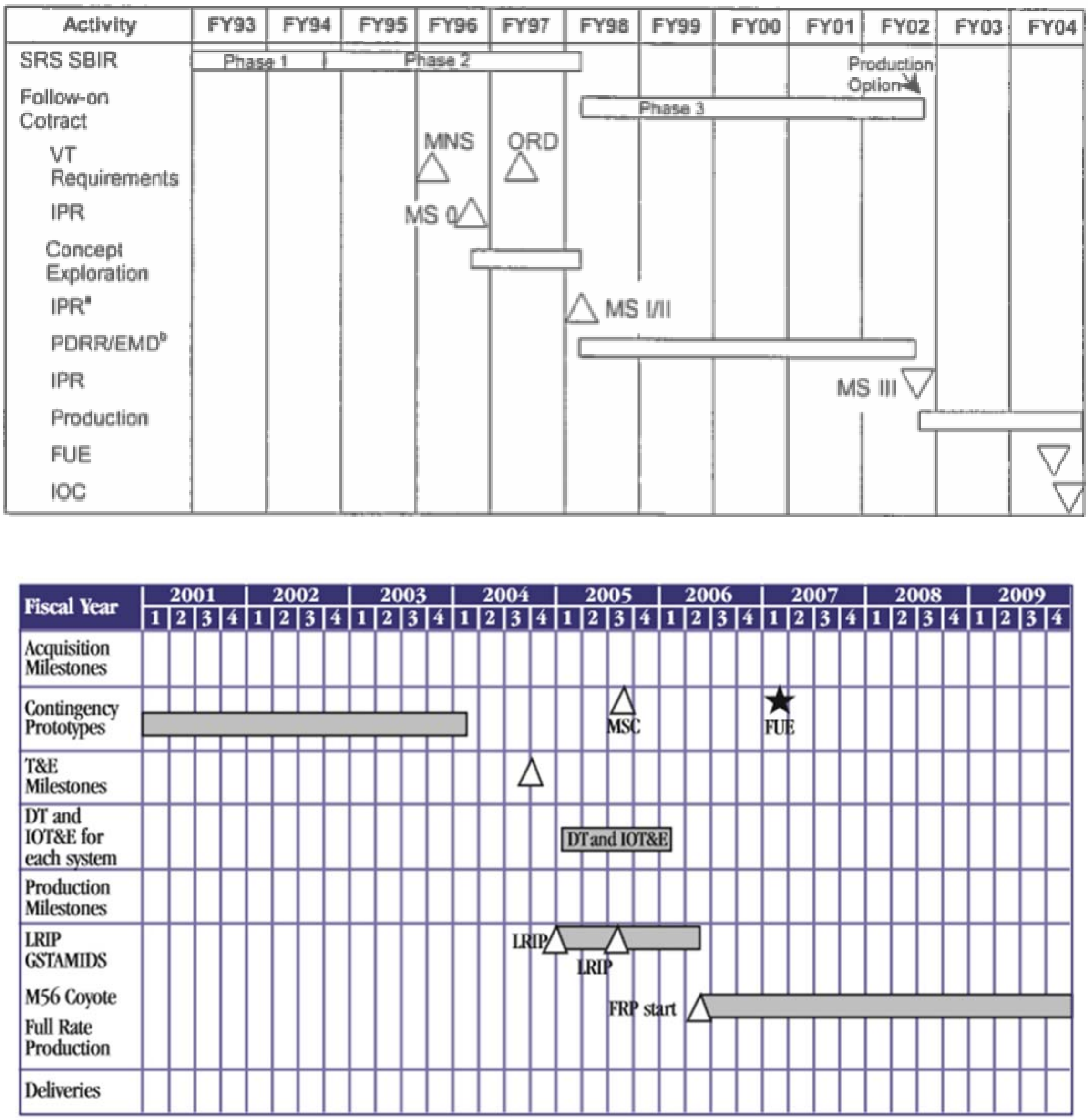


Figure 119. 2001 SRS Schedule Compared to 2003 CRS Schedule
(from DOD, 2001, 2003)

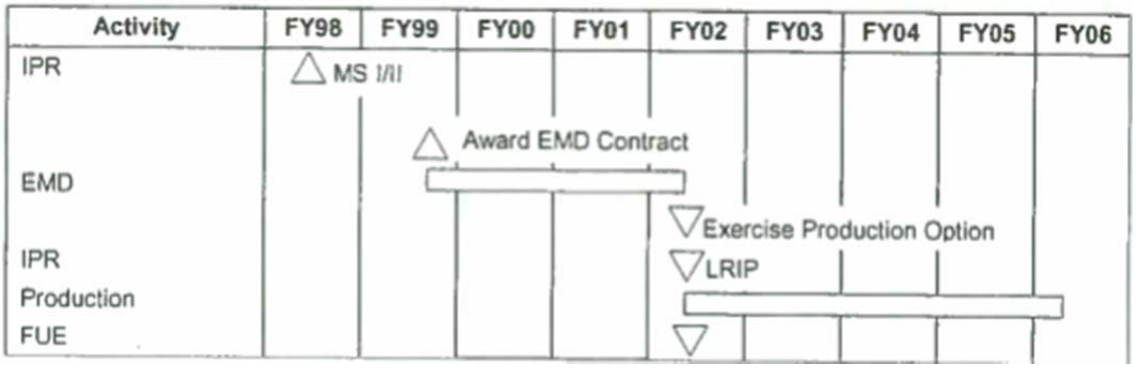
Table 44. 2001 SRS Funding Compared to 2003 CRS Funding (from DOD, 2001, 2003)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	9.6	6.5	2.0	TBD	0.0	0.0	0.0	0.0
Army	0.7[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total RDT&E	10.3	6.5	2.0	TBD	0.0	0.0	0.0	0.0
Procurement	4.0	6.6	2.4	3.0	TBD	TBD	TBD	TBD

SOURCE	FY02	FY03
JRP	3.6	8.8
Army	0.3[a]	1.0[a]
Total RDT&E	3.9	9.8

d. MDARS-I/E from 2001 to 2003

Since the last report, there have not been major changes or breakthroughs in this program, yet one piece of information emerged that was not presented in earlier editions. The MDARS system is expected to control a mix of 32 interior and exterior systems simultaneously. This is a large number of systems, and demonstrates the complexity and magnitude of this program. The MDARS name has not changed since its inception, and it continues with incremental developments, although the schedule does move further to the right almost every time this program is analyzed. In the last two years, the MDARS-I program conducted logistics demonstrations for inventory control in warehouses. The program also initiated preparatory steps for a Milestone C decision. Figure 120 compares the schedule for MDARS-I from 2001 to 2003 which shows Milestone C and LRIP shifting one year into the future compared to what was planned in 2001. The funding change for MDARS-I in the same period is shown in Table 45. The funding that was planned for FY02 in 2001 has decreased by about 85%, and the FY03 funding planned in 2001 is relatively unchanged.



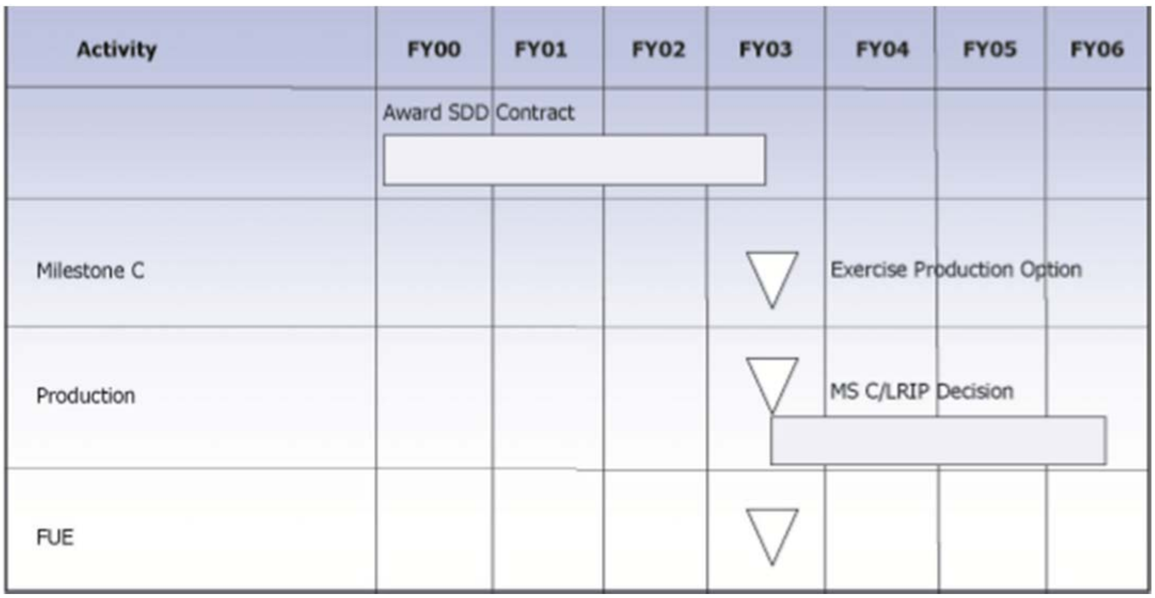


Figure 120. 2001 MDARS-I Schedule Compared to 2003 MDARS-I Schedule (from DOD, 2001, 2003)

Table 45. 2001 MDARS-I Funding Compared to 2003 MDARS-I Funding (from DOD, 2001, 2003)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	2.0	2.0	3.0	3.0	0.0	0.0	0.0	0.0
RDT&E Total	2.0	2.0	3.0	3.0	0.0	0.0	0.0	0.0

SOURCE	FY02	FY03
JRP	0.5	2.9
PSE	2.0	0
RDT&E Total	2.5	2.9

MDARS-E is on a different path than the interior system and is projected to achieve Milestone C later than its counterpart. In the past two years, the exterior system did award a contract to General Dynamics for system development and demonstration (SDD) and General Dynamics began production of the SDD prototype (DOD, 2003). Figure 121 compares the MDARS-E schedule from 2001 to the 2003 schedule and it can be seen that its planned Milestone C in FY05 has shifted to FY06 in the most recent JRPMP. The significant funding change for MDARS-E in the same period is shown in Table 46. The funding that was planned for FY02 in 2001 has increased by about 150%, and the FY03 funding planned in 2001 jumps by about 300%.

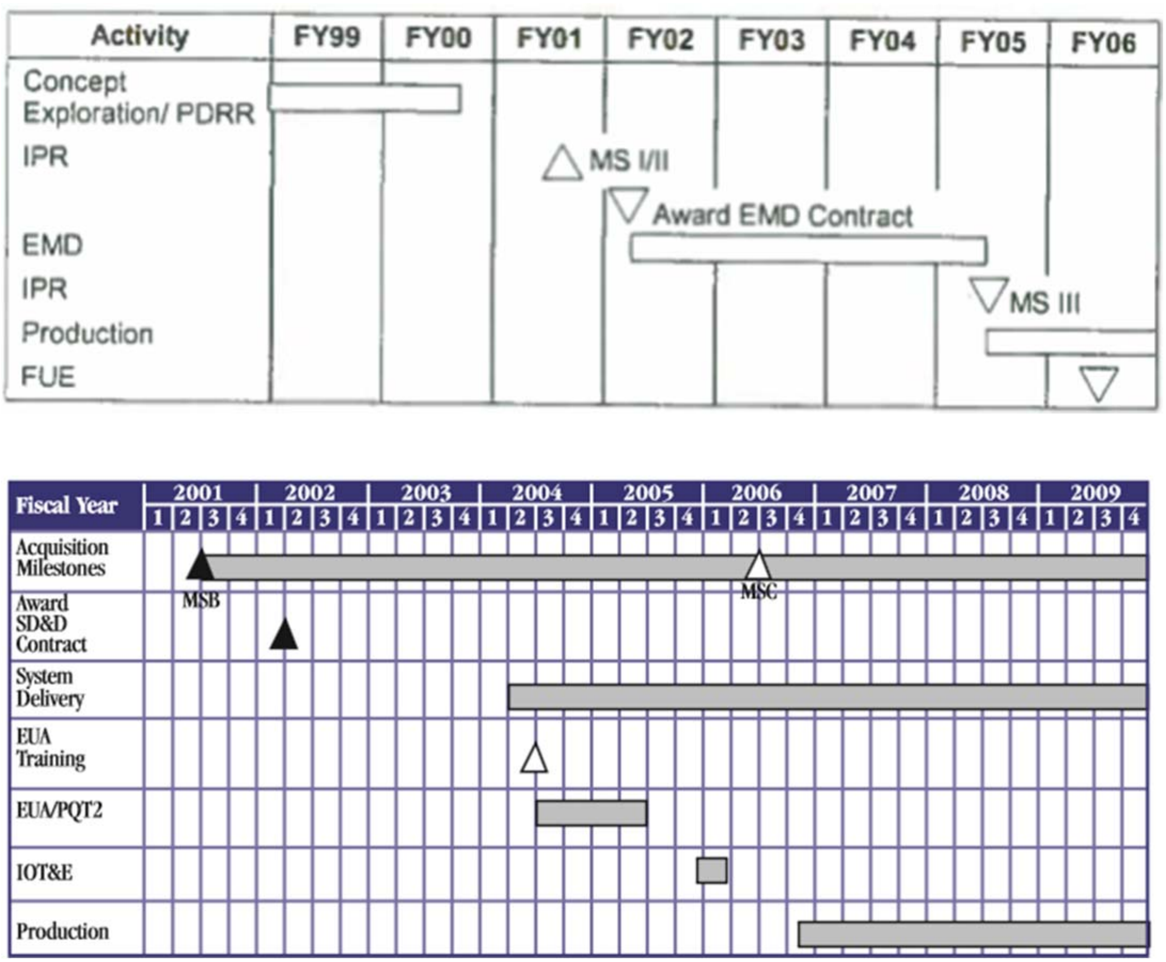


Figure 121. 2001 MDARS-E Schedule Compared to 2003 MDARS-E Schedule (from DOD, 2001, 2003)

Table 46. 2001 MDARS-E Funding Compared to 2003 MDARS-E Funding (from DOD, 2001, 2003)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	0.0	2.0	3.0	3.0	0.0	0.0	0.0	0.0
PSE	3.9	2.5	0.0	0.0	0.0	0.0	0.0	0.0
RDT&E Total	3.9	4.5	3.0	3.0	0.0	0.0	0.0	0.0

SOURCE	FY02	FY03
JRP	4.5	8.9
PSE	2.3	0.5
RDT&E Total	6.8	9.4

e. RCSS from 2001 to 2003

In 2001, the JRPMP informed readers that the mini-flair system will be replaced by another system in the RCSS program due to requirements that exceed the mini-flail's capabilities. This is obviously a longer-term plan since the 2003 JRPMP reports that six additional mini-flails have been acquired in the past two years; they are reserved for contingency operations (DOD, 2003). There is not a lot of significant progress reported on the new system or the program but a much clearer description of the system's expectations are presented. The new system's "missions may include: (1) wire breaching; (2) dispensing of obscurants; (3) emplacing demolitions; (4) sweeping runways, and (5) creating access lanes through buildings or other antipersonnel obstacles" (DOD, 2003, p. 77). One system key performance parameter (KPP) is that it must be able to operate through line-of-sight (LOS) out to 300 m. The vehicle will come with a standard issue of various tools that can be swapped based upon the mission set. This system is designed to conduct some of the most dangerous jobs; the ones that can result in the highest number of casualties, particularly during full-spectrum operations. This program has experience some of the smallest schedule change in the last two years; comparing the schedule and funding graphically is not necessary. The schedule presented in 2001 is almost identical in the 2003 JRPMP, Milestone C shifts right by about one quarter, which is not very significant. The funding planned for FY02 in 2001 has increased in the latest plan and

FY03 funding was never presented so the figure of $5.7 million in the 2003 master plan is a new projection.

f. MPRS/COBRA from 2001 to 2003

The combined operations battlefield robotics asset (COBRA) program is classified as a Soldier UGV or SUGV and is one of the UGV programs aligned with the Army future combat systems (FCS) program (DOD, 2003). In 2001, this program was called MPRS and included the URBOT and Matilda UGV systems. Since that report, 20 URBOTs and Matildas have been delivered to Afghanistan in support of Operation Enduring Freedom (OEF). These small, man-portable systems are likely carried in a pack or vehicle on combat patrols and deployed to search caves, culverts, and to inspect suspicious items on roads, paths, or even in buildings. Figure 122 compares the 2001 MPRS schedule with the 2003 COBRA schedule which shows Milestone B acceleration in the latest edition by one year, and Milestone C moving almost one year further into the future. Table 47 compares the 2001 MPRS funding with the 2003 COBRA funding; with an increase of about 75% in the 2003 plan compared to what was planned in 2001. No funding was planned for FY03 in the 2001 master plan, but the 2003 plan shows planned funding of $2.6 million, almost $1 million less than the year prior.

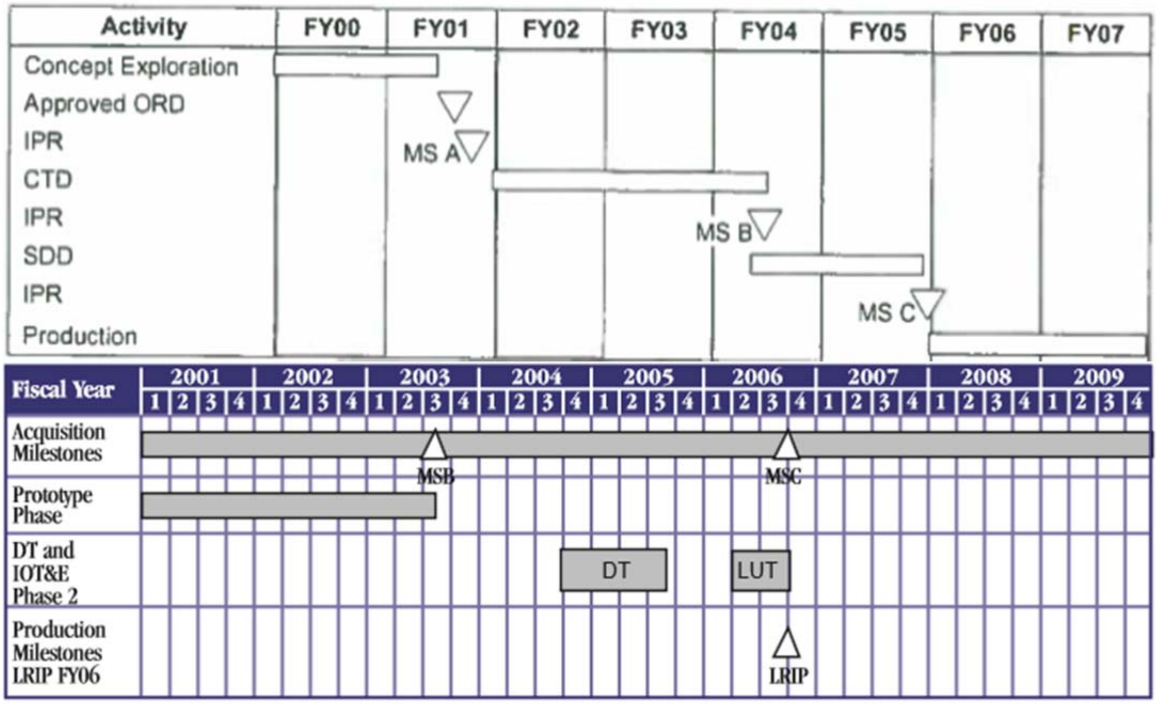


Figure 122. 2001 MPRS Schedule Compared to 2003 COBRA Schedule (from DOD, 2001, 2003)

Table 47. 2001 MPRS Funding Compared to 2003 COBRA Funding (from DOD, 2001, 2003)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	0.5	2.0	2.0	TBD	TBD	TBD	TBD	TBD

SOURCE	FY02	FY03
JRP	3.5	2.6

g. Intelligent Mobility Program (IMP) from 2001 to 2003

The IMP was presented in the 2001 master plan, but not much information was presented while the 2003 JRPMP gives some good background on this program. The key focus of this program is to achieve "Mobility metrics including: (1) endurance; (2) speed; (3) gap crossing dimensions; (4) side slope traversal; (5) soft soil traction, and (6) payload carrying capability" (DOD, 2003, p. 94). This program gained immediate popularity following the events that occurred on September 11, 2001. The ODIS system was utilized at various military installations to quickly search under vehicles at the entry points. As this program develops, more uses for the ODIS and T4 system jointly are being realized. Technology development in other programs is leading this program towards a marsupial system approach. The T4 may become the mother or host system that drives around and deploys ODIS systems where appropriate. The document also discusses the idea of the MDARS-I/E systems operating as the host marsupial vehicle that also deploys ODIS vehicles in warehouses and around facilities where the larger UGVs cannot inspect.

In the 2001 JRPMP, there was not a schedule presented for the IMP. Figure 123 is the first schedule presented for this program. Due to the infancy of this program, no milestones are presented at this time. The 2001 plan does set aside funding for this program, and Table 48 compares the 2001 projections with the 2003 plan. FY02 funding that was planned in 2001 is down by 200% in the latest version and FY03 funding in the 2003 plan is up by about 50% compared to what was planned in 2001.

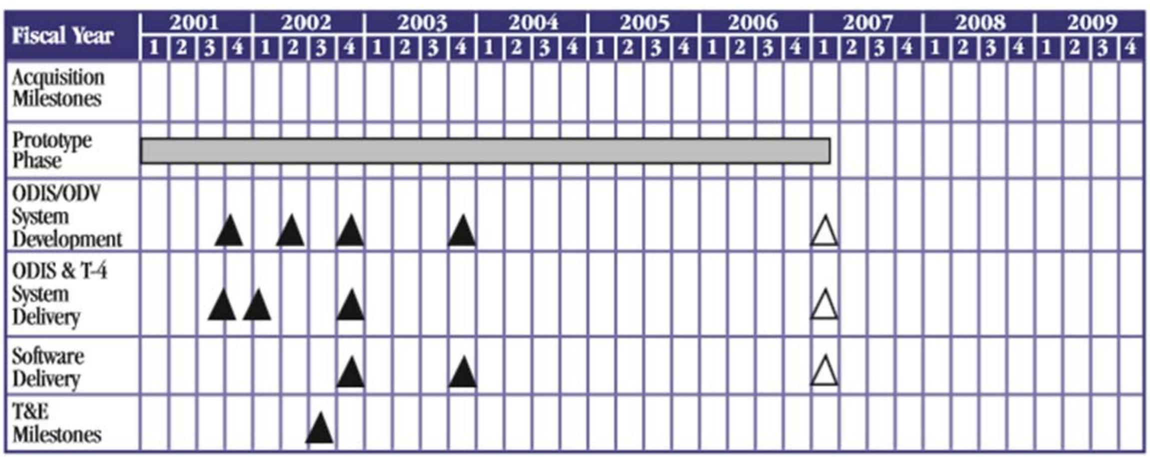


Figure 123. IMP Schedule (from DOD, 2003)

Table 48. 2001 IMP Funding Compared to 2003 IMP Funding (from DOD, 2001, 2003)

Source	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
JRP	3.0	5.2	3.0	2.0	2.0	2.0	2.0	2.0

SOURCE	FY02	FY03
JRP	1.0	2.9

h. JAUGS/JAUS from 2001 to 2003

The 2001 JAUGS program was not very descriptive about its purpose, but the 2003 JRPMP does a nice job of better explaining the joint architecture for unmanned systems (JAUS) program. In short, “JAUS will specify the data and message format interfaces to allow for rapid technology transfer” (DOD, 2003, p. 36). In the 2001 plan, there was no schedule for this program and readers learned that a Version 2.0 of the program was released. Figure 124 displays the 2003 JAUS program schedule with five focus areas: reference architecture specification, domain model, JAUS working group SOP, demonstration and validation, and commercial standards (DOD, 2003). As this program progresses, newer versions of each focus area will be released for stakeholders to adhere to in the arena of UGVs. Planned funding for this program has slightly increased in FY02 compared to what was planned in 2001 and there is now a planned fund for FY03 to the tune of $800,000. This information was not available in the 2001 plan. The ultimate goal of this program is to promote open architecture so that the DOD and other stakeholders do not get “locked into” the solution provided by one vendor or system and to ensure that technology can easily be transferred to other UGVs.

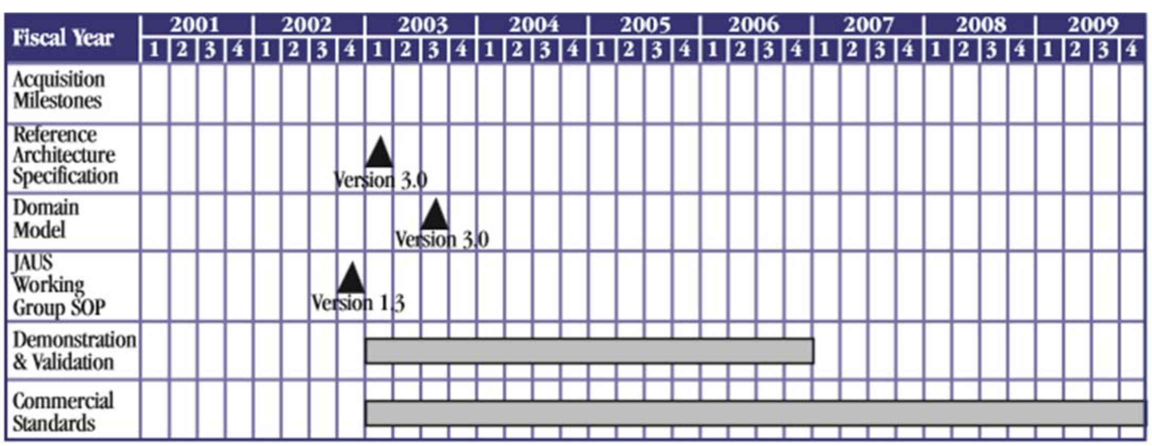


Figure 124. JAUS Program Schedule 2003 (from DOD, 2003)

i. RONS from 2001 to 2003

As a reminder, RONS is in full rate production and many UGVs have already been delivered to all military services. Not surprisingly, operations in Iraq and

Afghanistan, coupled with increased usage of IEDs by the enemy, have made this a useful system to the service members. However, the procurement numbers actually tell a different story. Table 49 compares what was delivered and planned in 2001 against what was delivered, on order, and planned in 2003. All services have actually reduced their objective in the past two years, except the Marines, who have increased their orders of the RONS by 18 systems. This may be a case of higher than planned costs for each system. Procurement funding for FY02 actually increases by about 275% compared to what was planned in 2001. Service specific procurement funding was not presented in 2001 so a comparison of overall program funding was conducted. In the 2001 JRPMP, no RONS procurement funding was planned for FY03, but there is funding to support the additional eight systems that are planned by the Army and Air Force. One other interesting note discovered in the 2003 master plan is that all of the accessories that can be connected to a RONS become a cost burden to the individual units that are fielded by the system. This additional equipment is not included with systems that are procured.

Table 49. 2001 RONS System Procurement Compared to 2003 (from DOD, 2001, 2003)

2001 RONS

2001	Army	Navy	Air Force	Marines	Totals
Delivered	49	28	30	0	107
Planned	49	28	84	11	172
Objective	98	56	114	11	279

2003 RONS

2003	Army	Navy	Air Force	Marines	Totals
Delivered	49	28	75	2	154
On Order	9	0	30	6	45
Planned	5	0	3	0	8
Objective	67	28	112	29	236

Delta	31	28	2	-18

j. MTRS (EOD Man Transportable Robotic System 2003

The MTRS program is quite possibly the most well-known and popular program in the UGV portfolio. This is because the PackBot made by iRobot and Talon made by Foster-Miller fall under this program. In FY01, users from all four military services conducted an analysis of alternatives (AOA) and recommended a strategy where commercial items are modified, acquired, used, and evolutionary improvements are made over time. MTRS was initially designated as an abbreviated acquisition program; the steps were also initiated to make this a formal acquisition program (DOD, 2003). Though the 2003 JRPMP does not directly state it, it is assumed that combat operations in Iraq and Afghanistan are the driving force behind this push to fill a capabilities gap. The gap appears to be a small system that can be carried by one to two people, have manipulators to conduct work, be quickly deployed, and be able to provide adequate standoff from hazardous explosives.

Figure 125 is a picture of the Talon (left), a 100-lb tracked vehicle and PackBot (right), a 40-lb tracked vehicle, from the 2003 JRPMP (DOD, 2003). The EOD technician controls the system with an OCU and can deploy the system using wireless communications; alternatively, a cable can be connected from the OCU to the robot to form a tethered connection. Each system has a control arm that can be manipulated to pick up items and cameras to conduct reconnaissance.

Figure 125. Picture of Talon (left) and PackBot (right; from DOD, 2003)

It makes sense to quickly highlight some key events to demonstrate how quickly an acquisition program can produce results given the right conditions. In FY01 the AOA was conducted. In May 2002, proposals were solicited to vendors. In June and July 2002, the proposals were reviewed and evaluated. In October 2002, two contracts were awarded, one to iRobot Corporation and one to Foster-Miller, Inc. A production approval will occur and the government plans to exercise a contract option that yields 250 units over a three-year period with commitments for system support and continuous evolutionary improvements (DOD, 2003). By February 2003, seven Talons and two PackBots were delivered. This is a lot of progress within a two-year period and demonstrates how quickly items can go from requirement to delivery. This same process will prove a future challenge as it relates to the sustainment phase of this program.

Figure 126 is the first schedule presented for the EOD MTRS program. While not elaborate, it serves as a good starting point. The MTRS milestone marker depicted in the second quarter of 2005 is believed to be Milestone 0, when the program will formally initiate. Table 50 is the first EOD MTRS funding chart. The Navy assumes most of the funding for this program, as it generally does with EOD based UGV programs such as the RONS.

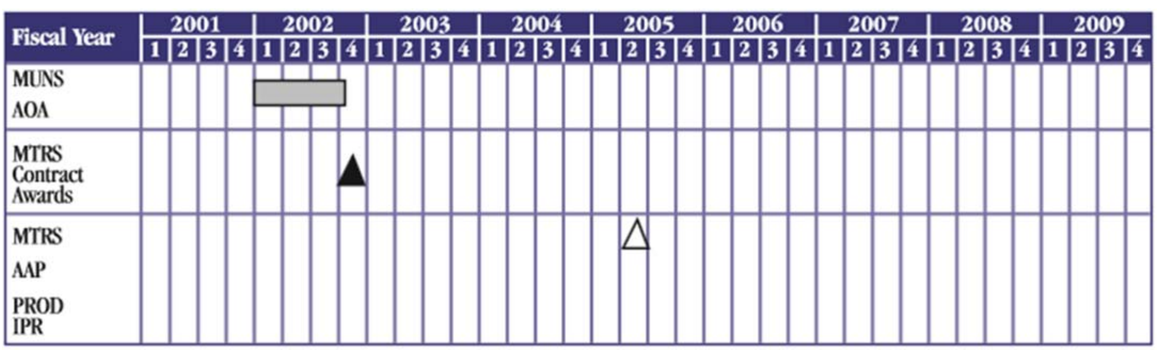


Figure 126. First MTRS Schedule (from DOD, 2003)

Table 50. First MTRS Funding Schedule (from DOD, 2003)

SOURCE	FY02	FY03
JRP	0.3	1.0
Navy	0.7	1.1
Total	1.0	2.1

k. *RF (Robotic Follower ATD; Advanced Technology Demonstration) 2003*

The RF ATD program has roots that stem from the DEMO III+ program with deeper applications that support other initiatives. The primary purpose of RF ATD is to provide near-term technologies to UGV systems that are in development under the Army future combat systems (FCS) program.

The gist of this program is that there is a lead Soldier or vehicle that carries a piece of equipment that gathers information and transmits it back to the follower vehicle. The follower UGV then operates semi-autonomously and travels the path of least resistance, placing minimal workload on any humans. Practical applications and uses for this program include "(1) ruck carrier; (2) supply platoon; (3) non-line-of-sight (NLOS)/beyond line of sight (BLOS) fire, and (4) rear security" (DOD, 2003, p. 95). This program will be demonstrated on XUVs in the DEMO III+ program. Two troop carrier vehicles can demonstrate convoy operations, where the vehicles follow at high speeds but within LOS of lead vehicles. The multifunction utility/logistics equipment (MULE) will also be used to demonstrate this technology in support of dismounted troops in rugged terrain, as speed slows.

Figure 127 depicts the first RF ATD program schedule on record. There are no formal milestones presented on the schedule, but a contract was awarded in FY01 for this program. The first experiment is planned for FY03 so results of this experiment are expected in the next master plan. Experiment II is planned for FY05 with no funding data provided anywhere in the 2003 JRPMP.

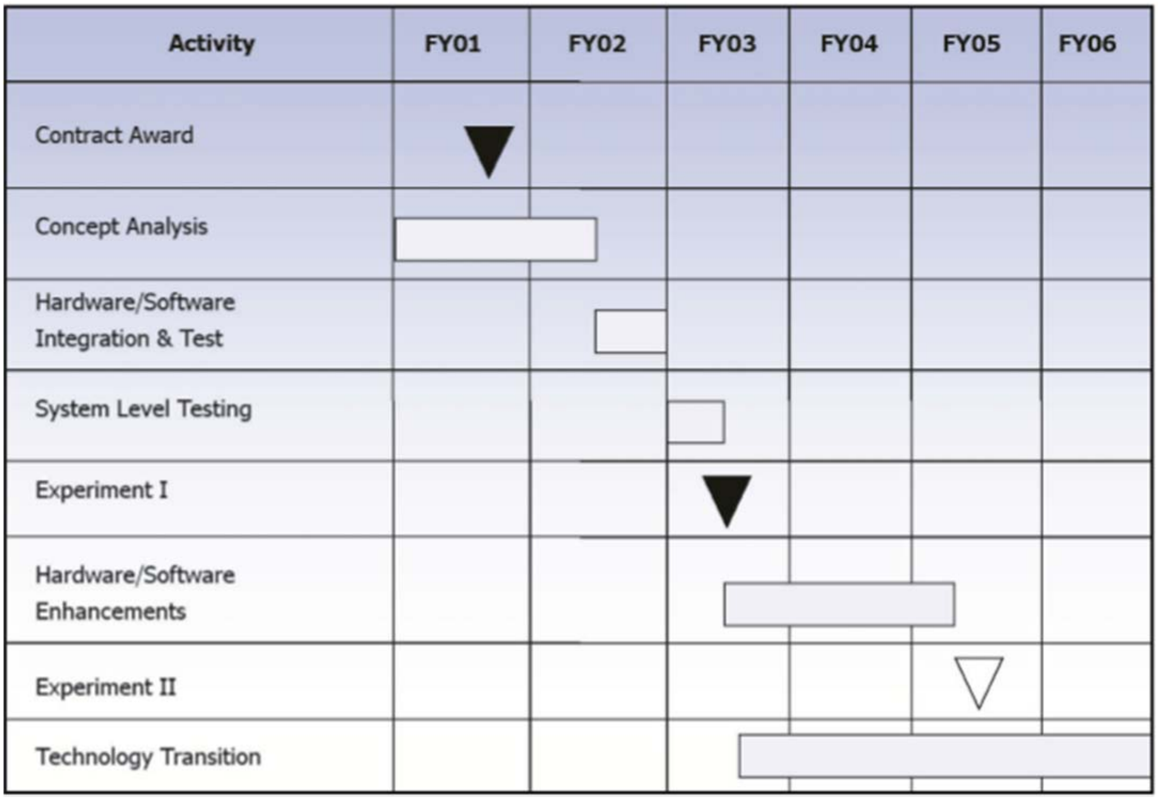


Figure 127. RF ATD Program Schedule (from DOD, 2003)

l. CAT (Crew Integration and Automated Test Bed) ATD 2003

The CAT ATD is a new program in the 2003 JRPMP. “The purpose of the CAT ATD is to demonstrate the crew interfaces, automation, and integration technologies required to operate and support future combat vehicles” (DOD, 2003, p. 98). If successful, this program will result in highly sophisticated FCS vehicles that are manned by two individuals with the ability to control up to 10 unmanned systems. This is currently being tested on Bradley fighting vehicles (BFV) and Stryker vehicles, but will transition to vehicles being developed in the FCS program.

The key drivers to this program’s success are driving aids and automation technologies (DOD, 2003). The profile of this program is not very detailed, but it appears that the two-man vehicle will serve as the command and control (C2) node for a variety of UGVs and unmanned aerial vehicles (UAVs) that are expected to conduct reconnaissance, direct fire engagements, and perform other routine missions executed by warfighters. This seems to be a lofty and challenging goal considering that highly autonomous operations are not achievable at this point in time. Another risk is the vulnerability of a vehicle with only two crew members potentially operating too far from the support of the manned force.

Figure 128 depicts the first CAT ATD schedule presented in the 2003 JRPMP. This schedule is similar to that of the RF ATD program. The contract has already been awarded and experiment I is planned for FY03 and experiment II in FY05. No funding for this program is presented anywhere in the 2003 master plan.

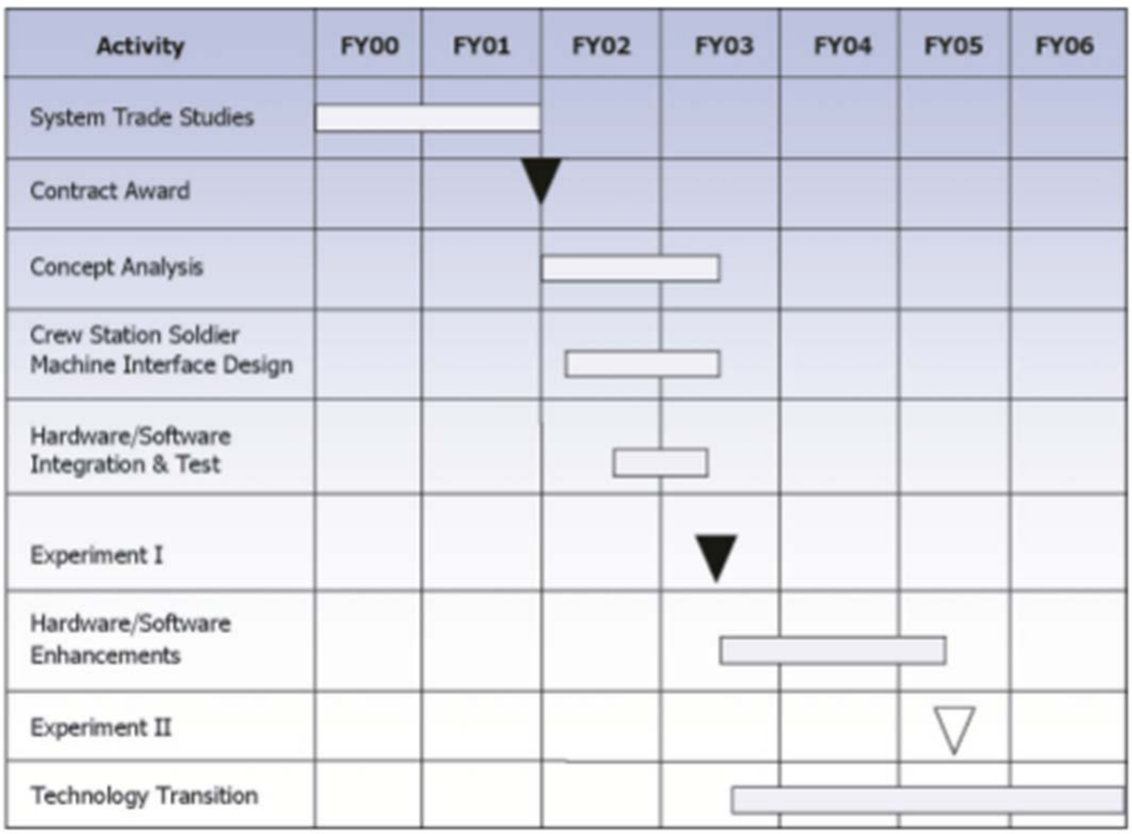


Figure 128. CAT ATD Program Schedule (from DOD, 2003)

m. NGEODRCV (Next Generation EOD Remote Controlled Vehicle) 2003

This is a new program in the 2003 JRPMP. It is a collaborative effort that links together many organizations within the government, industry, and academia to advance existing technology and develop state-of-the-art technology for the future. The program structure and members involved is shown in Figure 129. The Air Force Research Laboratory is the overall lead for this program.

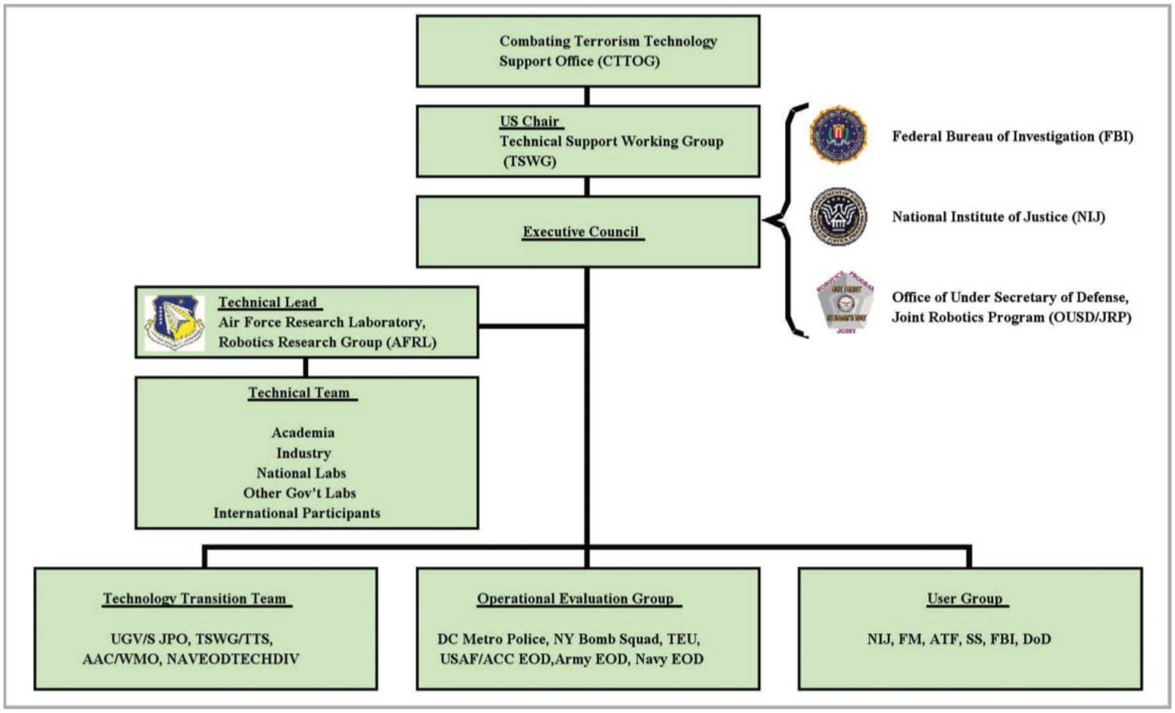


Figure 129. NGEODRCV Program Structure (from DOD, 2003)

This program does have a specific strategy which "involves exploiting the capabilities, proven technologies, and innovative ideas from government institutes, industry, academia, and international partnerships" (DOD, 2003, p. 102). The idea is to use open architecture to ensure that technology can be easily and affordably transferred between multiple programs. The focal points of the research include EOD tools, lighter power generation, lighter material to make robots, and sensor advances (DOD, 2003). This concept exists within the DOD through the joint architecture for unmanned systems (JAUS) program, but this is an excellent opportunity to gain industry-wide sharing among many entities outside of the DOD, but that have a vested interest in UGV technology development.

Figure 130 presents the first NGEODRCV program schedule. Milestone A is not expected until late in 2006, and Milestone B is planned for late 2008. The program funding shared among three different organizations, one of which is the JRP is shown in Table 51.

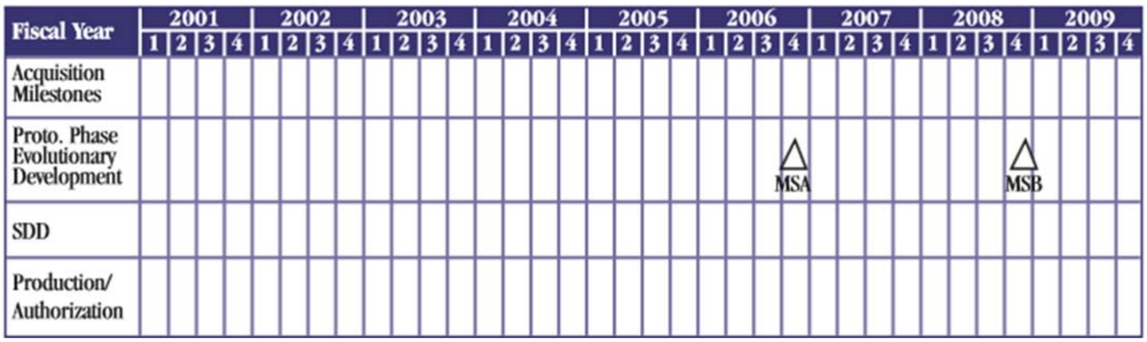


Figure 130. NGEODRCV Program Schedule (from DOD, 2003)

Table 51. NGEODRCV Funding (from DOD, 2003)

SOURCE	FY02	FY03
TSWG	0.5	.5
JRP	0.3	0.0[a]
OGA	2.0	1.0
TOTAL	2.8	3.5

n. Conclusion

In two years' time, the UGV program grew significantly in terms of numbers of programs and in terms of funding towards the overall program. Almost all programs from the 2001 JRPMP remained in place or became part of another program. In addition, two new programs were added to the portfolio. The BUGS program, which seemed to disappear, was actually merged with the ARS system program under RACS.

During this period, the U.S. military is now involved in combat operations in the Balkans, Afghanistan, and Iraq. The complexities of the modern battlefield pose new and dynamic threats to warfighters that demand UGV support to reduce unnecessary exposure to risk. In past editions of the master plan, the CRS program was the major push based on the demand for teleoperated mine clearance vehicles in Bosnia and Kosovo. The current threat in Afghanistan and Iraq calls for the clearance of caves, urban terrain, and reconnaissance/neutralization of IEDs. The trend also appears to be shifting towards UGVs that support the EOD technician, such as the man transportable robotic system (MTRS).

There are a lot of programs running simultaneously and in some regards the efforts appear redundant. The advantage to multiple programs, however, is that successful technology can be shared with other programs, especially through the emphasis created by the JAUS program. Open architecture and collaboration among government, academia, and industry will result in shared R&D costs, technology maturation, technology breakthroughs, and ultimately, reduced life cycle costs.

The UGV program has certainly grown in size and there appears to be increased demand for UGVs by warfighters and even civilian agencies. However, many of the programs continue to display schedule slippage with each new master plan, and few programs achieve full rate production. Funding appears to be on the rise, which is expected with a larger portfolio; however, even programs that are in full rate production are experiencing cost growth for less units when a basic comparison is done between previous plans. It appears that this technology simply has a high cost, especially because it is not mature.

3. 2004 Joint Robotics Program Master Plan

The 2004 JRPMP is the last of its kind; beyond this, the term *master plan* no longer exists in the UGV world and will be replaced by a document called a road map. This is also the end of individual program schedules and funding. At best, there is a UGV program master schedule and master funding table.

In the last year, the overall UGV portfolio has grown again. This year, there are three new programs that have not been seen in previous master plans. Additionally, a new system is present under the RACS program, called the STORK. This brings the total number of systems under RACS up to five.

The document reports that Congress appropriated another $12 million on top of the $24 million that was added the year prior. This money is designed to sustain current systems and accelerate program objectives (DOD, 2004). The 2004 JRPMP points out that the war in Iraq has transitioned from full spectrum to stability operations and that warfighters face a significant improvised explosive device (IED) threat. This threat has resulted in increased demand for UGVs; 162 new UGV systems are on their way into various theaters of operation at the time this report was written (DOD, 2004). The goal of the JRP is to get useful technology and systems into the hands of users as quickly as possible. This sounds like the foundation of massive deliveries of robotic systems via joint urgent operational needs statements (JUONS) requests.

Figure 131 compares the 2003 and 2004 JRP master milestone schedule. One immediate standout is that the combined operations battlefield robotics asset (COBRA) program is no longer present on the schedule, and this section determines the status of COBRA. Each program's schedule is covered in greater detail below. Table 52 compares the overall UGV program funding from 2003 to 2004. Surprisingly, only three programs show any funding changes from what was planned the year prior; joint service EOD, all-purpose robotic transport system (ARTS), and next generation EOD remote controlled vehicle (NGEODRCV). The specifics of the changes are covered under each program's section. Figure 132 compares the summary of JRP weight classes chart from 2003 to the latest version in 2004. Many of the systems have changed weight class in the past year. Some systems are lighter, which may be a result of the NGEODRCV program. Some systems are heavier, which could be explained by the adding of capabilities to the platform; this is explored in greater detail.

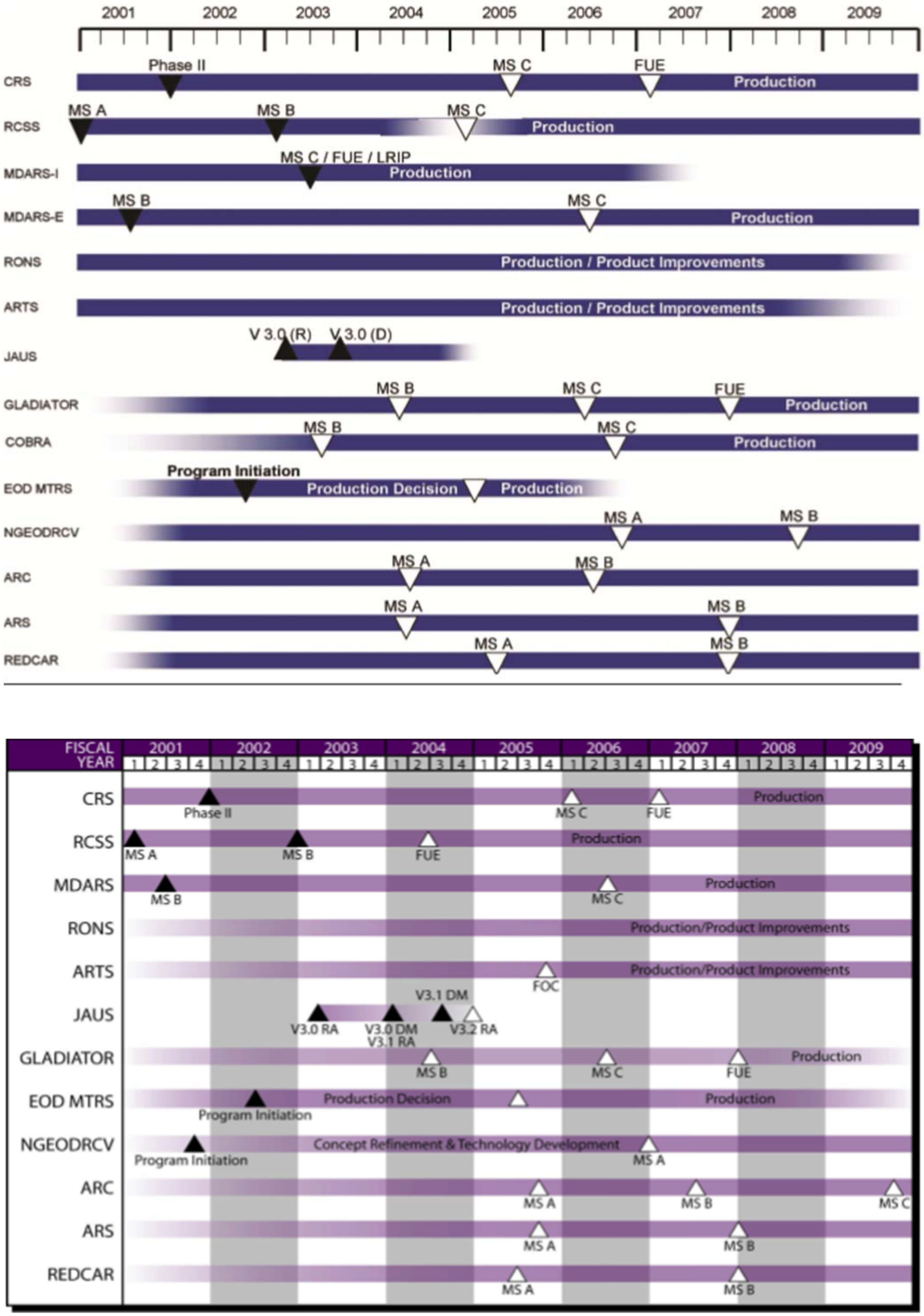


Figure 131. 2003 UGV Master Schedule Compared to 2004 UGV Master Schedule (from DOD, 2003, 2004)

Table 52. 2003 UGV Program Funding Compared to 2004 Program Funding (from DOD, 2003, 2004)

PROJECT	FY02	FY03
RACS	4.3	2.5a
JAUS	0.8	0.8
MDARS-E	3.7	8.9
MDARS-I	3.4	2.9
CRS	3.6	8.8
GLADIATOR		2.9
RCSS	4.3	5.7
EOD MTRS	0.3	1.0
COBRA	3.5	2.6
JT SVC EOD (RONS)	0.8	2.1
TARDEC	1.0	2.9
Tech Base	0.0[b]	1.0
SPAWAR	–	4.0

Project	FY03	FY04
RACS	2.5[a]	6.3[a]
JAUS	0.8	1.4
MDARS	8.9	1.0
CRS	8.8	2.4
GLADIATOR	2.9	8.2
RCSS	5.7	2.0
Joint Service EOD	2.1	3.3[b]
Intelligent Mobility	2.9	0.8
Robotic Systems Pool (COTS)	4.0	5.6
ARTS	0.5	0.5
NUSE2	-	3.7
Next Generation EOD RCV	2.0[c]	2.0

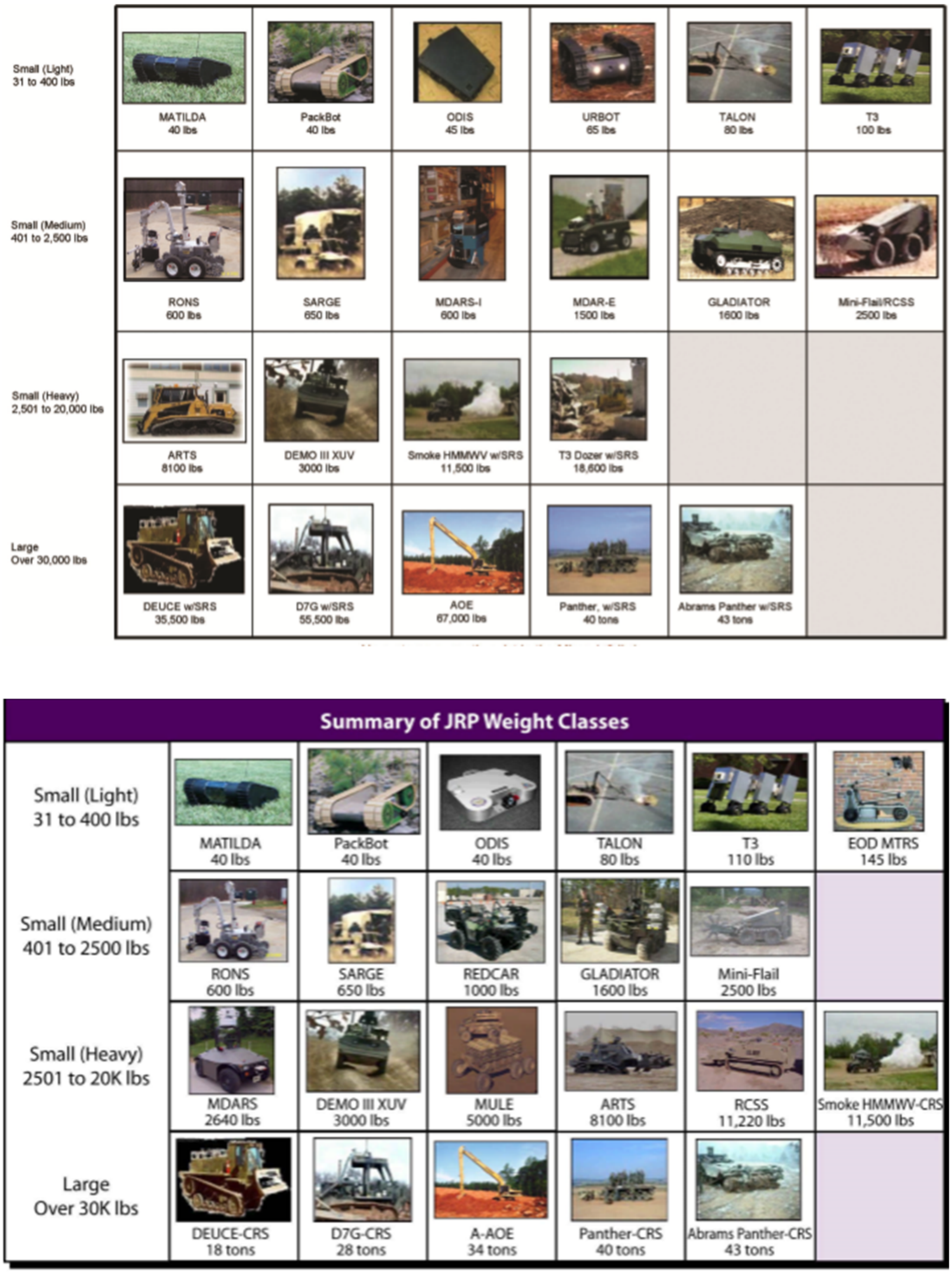


Figure 132. 2003 JRP UGV Weight Class Compared to 2004 JRP UGV Weight Class (from DOD, 2003, 2004)

a. Gladiator from 2003 to 2004

In the past year, the Gladiator TUGV has been deployed to two Marine battalions where tactics, techniques, and procedures (TTPs) were developed by the warfighter for this system. The 2004 JRPMP explains well the true purpose of the Gladiator. It is now known that the system is designed to support dismounted troops on the battlefield. The only issue with this is that the Gladiator is large and classified by JRP as a small (medium) system and its weight is 1600 lbs. While it likely provides great support to dismounts, the dismounts cannot return the favor. The system would require another vehicle for recovery if it were disabled. Figure 133 is the latest picture of the Gladiator system; it gives a good idea of the size of the UGV.

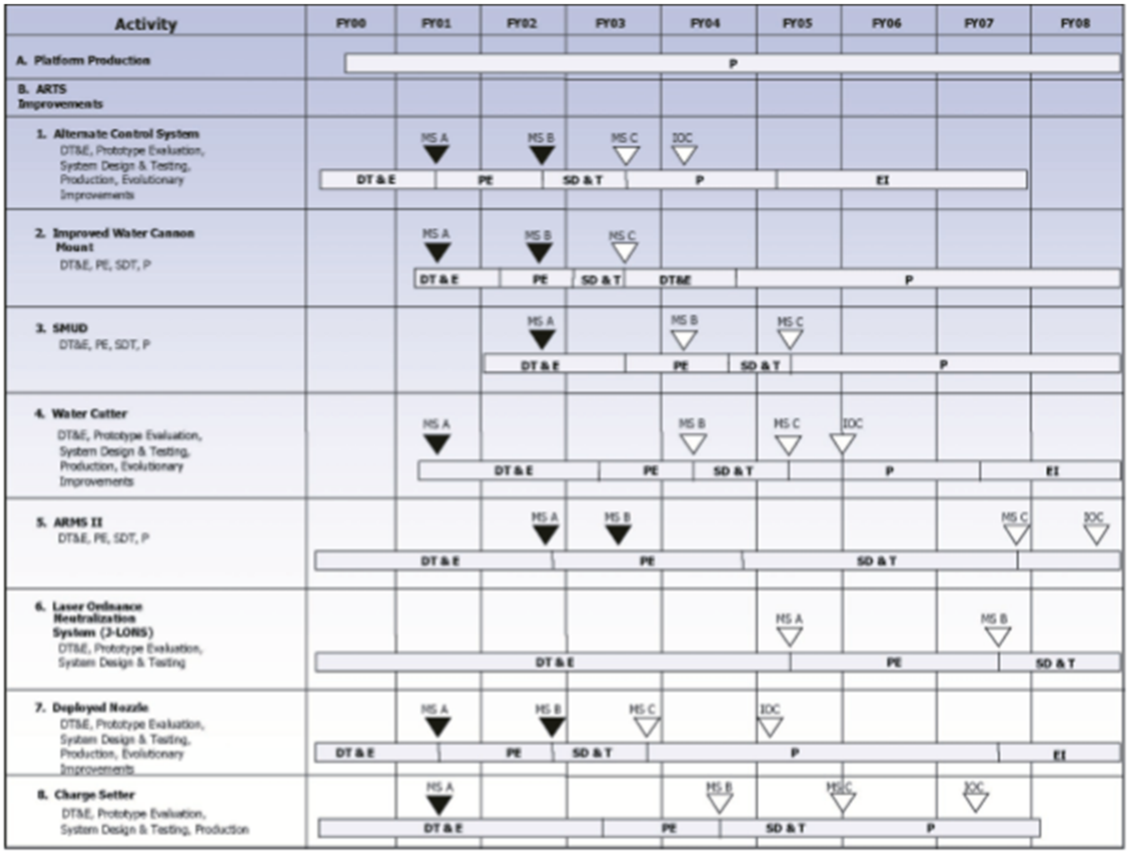
Figure 133. Picture of Gladiator (from DOD, 2004)

The Gladiator system will now consist of the base unit, an operator control unit (OCU) and one of four mission payload modules (MPM). The four MPMs include "Anti-personnel/obstacle breaching system (APOBS), joint chemical agent detector (JCAD), light vehicle obscurant smoke system (LVOSS), and non-lethal area denial and crowd control weapons, and lethal direct fire weapons" (DOD, 2004, p. 5–8). Based on the mission at hand, the Marines can choose which payload will best accomplish the mission.

A comparison of the 2003 and 2004 Gladiator program schedule and funding was conducted with surprising results. In the last year, there was no change to either. This is the first time that the schedule and funding for this program have gone unchanged when two consecutive years are compared. This is a good sign that this program is running smoothly and that a TUGV may actually get fielded to an operational unit in the near future.

b. RACS (ARTS, ARC, ARS, REDCAR, STORK) from 2003 to 2004

The all-purpose robotic transport system (ARTS) system is in full rate production but there is much to report on this program. In the 2003 JRPMP there were only eight ARTS components on the program schedule, each with their own milestone. In the 2004 JRPMP, there are 11 components: seven of the eight original remain and four new components are added. Figure 134 compares the 2003 ARTS program improvements to the 2004 ARTS program improvements. Of all components carried over from last year, two have actually adjusted the schedule to achieve production one year earlier than expected. The two components are the improved water cannon mount and the articulated remote manipulator system. Two components also fell behind schedule by at least one year for the alternate control system and greater than one year, but time unknown, for the water cutter. The funding that was planned for FY03 in the 2003 master plan has dropped significantly in the latest edition. A comparison of the 2003 and 2004 ARTS funding is shown in Table 53 and depicts an 80% reduction in funding for FY03 compared to what was planned a year earlier.



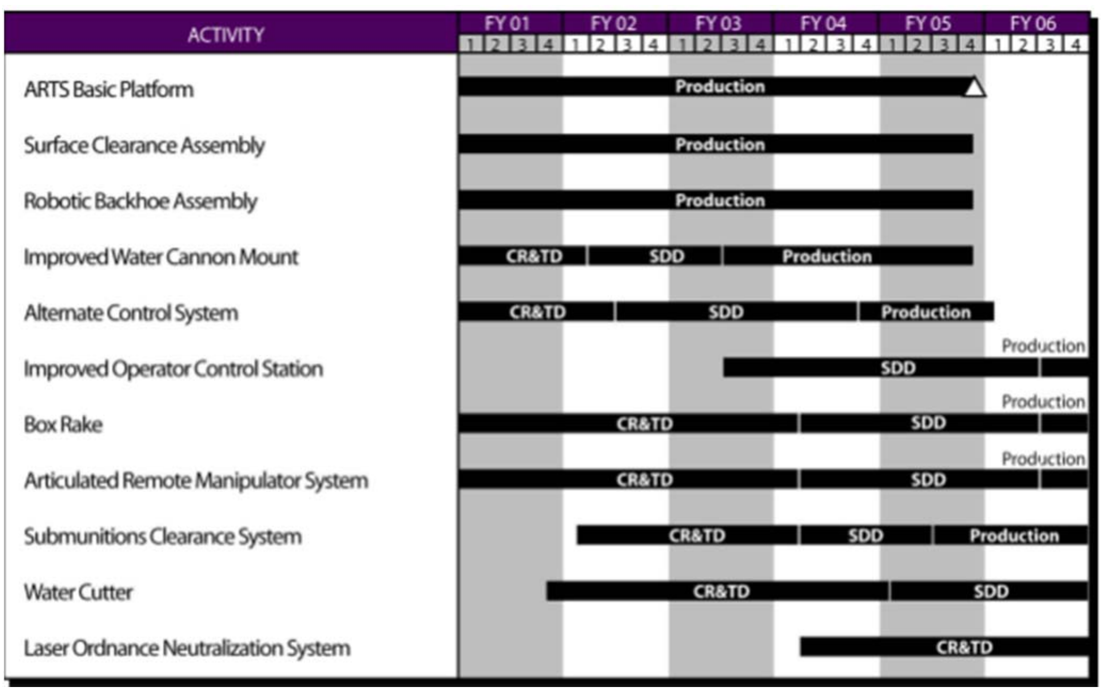


Figure 134. 2003 ARTS Schedule Compared to 2004 ARTS (from DOD, 2003, 2004)

Table 53. 2003 RACS/ARTS Funding Compared to 2004 ARTS Funding (from DOD, 2003, 2004)

SOURCE	FY02	FY03
JRP	4.3[a]	2.5[a]

[a] RACS funding includes ARTS, ARS, ARC, REDCAR, and NGEODRCV technology demonstration programs as well as systems development and demonstration funding for Active Range Clearance and Airborne Civil Engineering executed by Combat Support Systems (AAC/WMO).

Source	FY03	FY04
JRP	0.5	0.5

Aside from the program troubles with the schedule and funding, there seems to be an accountability of systems issue in the 2004 master plan. In 2003, it was reported that there were 42 ARTS delivered and 20 more planned for delivery for a total of 62 systems. A change in procurement is not uncommon, but the numbers in 2004 do not add up correctly. The 2004 plan states that 46 ARTS have been delivered through FY03 and an additional two ARTS are designated as test systems. The master plan then states that 30 more systems will be produced and delivered for a total of 72 ARTS by FY05. This does not add up correctly; the numbers actually add up to 78 total ARTS (DOD, 2004). Either this breakdown is poorly explained and the numbers are misinterpreted, or there is a typo in the total system count.

Active range clearance (ARC) is the second system under the RACS program and not a lot of information is presented about this program in the 2004 JRPMP. In fact, there is nothing significant to report besides the schedule change. Figure 135 compares the 2003 ARC schedule with the 2004 ARC schedule. The 2004 schedule shows more detail for each schedule activity, but there is also a slip in the overall schedule. Milestones A and B have shifted one year further into the future than originally planned. Milestone C is unchanged and is still planned for FY09.

In the robotics for agile combat support (RACS) program, funding is shown for RACS as a whole and for ARTS, but never for the other individual systems. Last year, ARTS accounted for about 70% of the total program funding and this year it only accounts for 20%. Since there are five systems in RACS, the assumption is that each program receives 20% of funding.

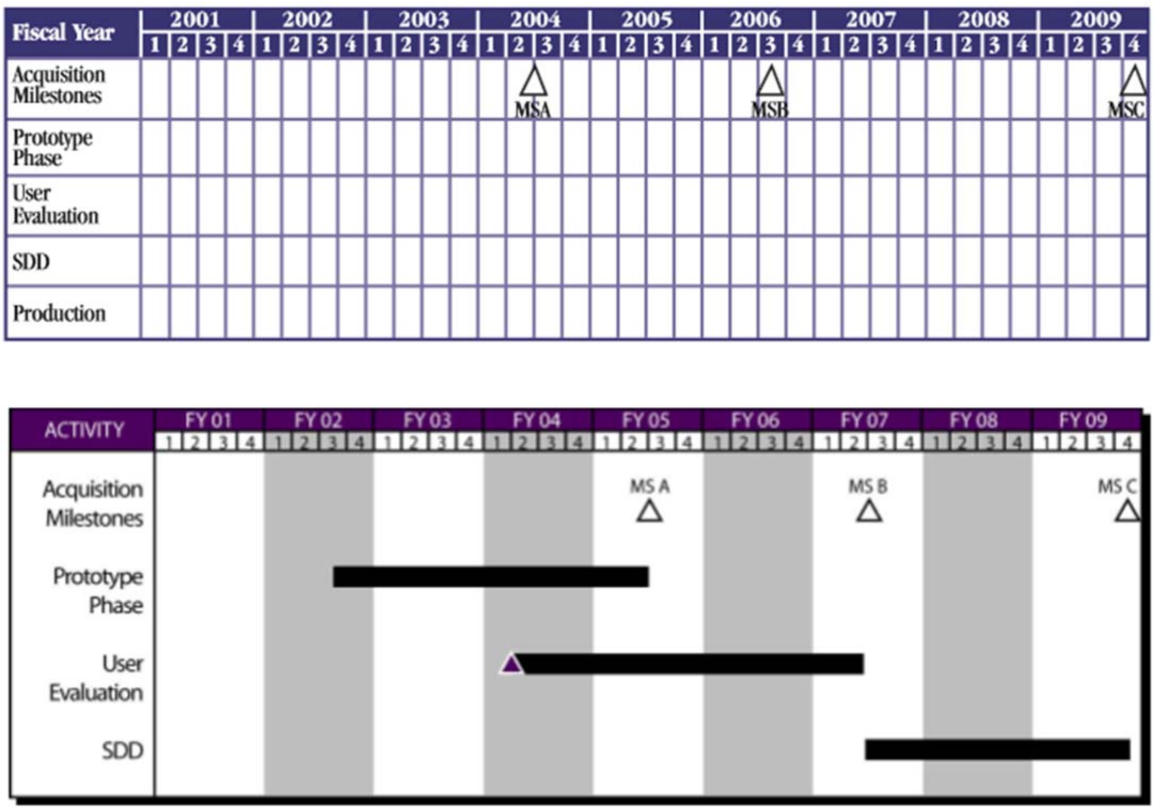


Figure 135. 2003 ARC Schedule Compared to 2004 ARC (from DOD, 2003, 2004)

Advanced robotic systems (ARS) is the third system under the RACS program. Much like the ARC program, nothing significant is reported within the last year. Figure 136 compares the 2003 ARS schedule with the 2004 ARS schedule. The only significant change to the schedule is a shift of Milestone A from FY04 to FY05 in the past year. It is apparent that more detail has gone into the latest schedule, and the activities are based on a time line. As reported under the ARC system, it is believed that the ARS constitutes 20% of the RACS funding, but no ARS specific funding is provided to confirm this assumption.

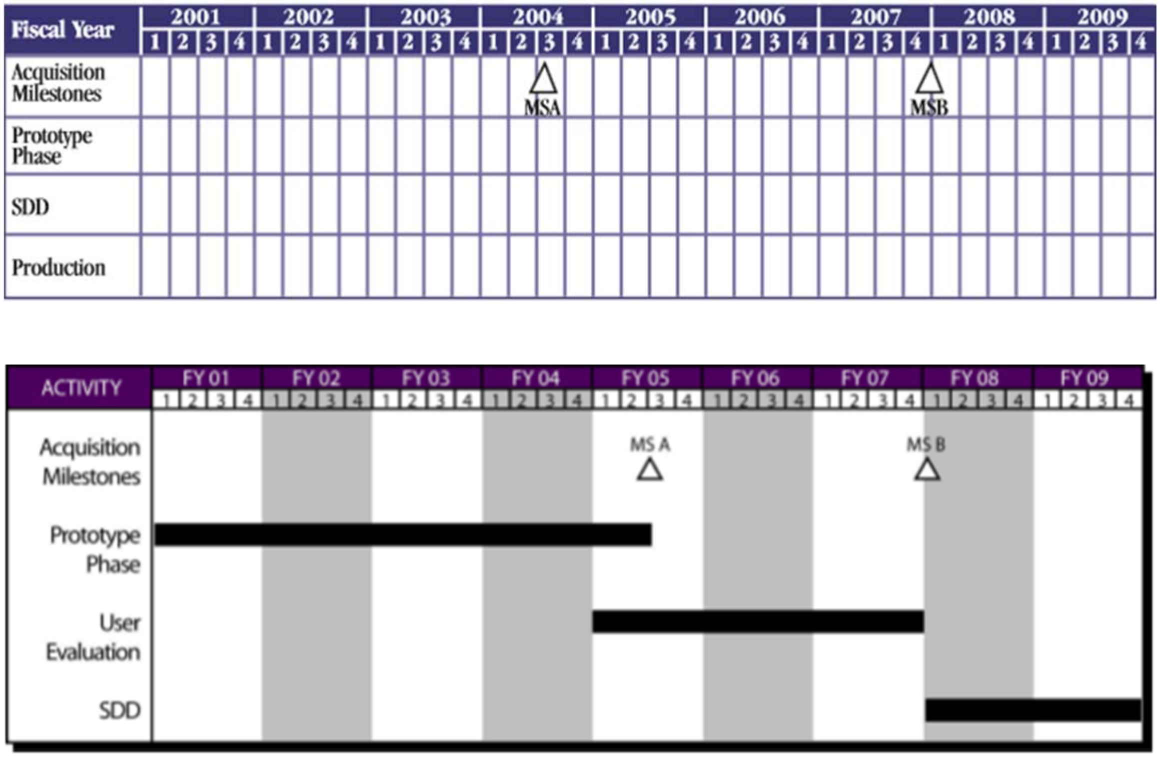


Figure 136. 2003 ARS Schedule Compared to 2004 ARS Schedule (from DOD, 2003, 2004)

Remote detection, challenge, and response system (REDCAR) is the fourth system in the RACS program. In the 2003 JRPMP, this was a new system and limited information about the program was available. This year, the 2004 JRPMP explains the technical aspect of REDCAR. “REDCAR will use at least three different robotic platforms: (1) a surveillance platform, MDARS; (2) an engagement platform, REDCAR SCOUT; and (3) a small-scale platform for limited access areas” (DOD, 2004, p. 6-22). The goal is for REDCARS to work with the MDARS program, most likely for the established security aspects of autonomous operation in controlled environments. Air Force installations will be similar to the environments where MDARS currently operate. The second system that REDCAR will work with as it develops is the PackBot. This is most likely because the PackBot is small and can fit under spaces below 30 in. tall, which is a prerequisite for the small system in the REDCARS program (DOD, 2004). The PackBot also has an arm that can manipulate objects and open doors and a camera that is organic to the system.

It appears that as the system grows in level of aggressiveness, the more capability it develops. The systems are characterized as small, surveillance, and engagement capable. The small system will be slow and deployed for investigation of specific targets. The surveillance vehicle is planned to travel up to 15 miles per hour across various terrain, and employ strobe lights, a speaker/microphone, and a non-lethal weapon. The engagement vehicle is planned to travel at speeds of up to 40 miles per hour across various terrain, and it will have all features of the surveillance vehicle plus infrared and color cameras, a human decoy system, and a lethal weapon (DOD, 2004). As previously stated, the engagement platform of this system does not seem feasible at this point in time. Manual override for engagements will likely be required for many years to come.

The REDCAR schedule paints a positive picture for this program. In the past year, no changes to the schedule are observed; and all milestones remain where they were planned the year prior. The 2003 schedule listed more activities that were not filled out, and this year many of the activities were eliminated. No funding information is available for this particular system. It is assumed to receive 20% of the RACS budget.

Project STORK is the fifth and final RACS program. It is a new addition to the 2004 RACS program. The gist of this program is that an unmanned aerial vehicle (UAV) delivers a UGV to a designated area via parachute, and the UAV serves as a communication relay to extend the coverage area of the UGV, beyond what can be achieved with an OCU. The 2004 master plan states that in a 2003 demonstration, the STORK was able to serve as a relay for a UGV that was located 26 km from its OCU. No schedule or funding information is presented for the STORK in the 2004 JRPMP.

c. CRS from 2003 to 2004

In the past year, there have not been any major breakthroughs with the common robotic system (CRS) program, but the system will be fitted to a new vehicle. The new CRS capable vehicle is called the ground standoff mine detection system (GSTAMIDS). The main demand for this program remains primarily in the clearing of mine fields. The system also has the ability to support in breach operations, but no information is provided that discusses the CRS and its use in Afghanistan or Iraq. With the increase of IEDs in

Iraq and the constant use of military supply routes (MSR), it is surprising that this vehicle is not used heavily for clearance operations.

Figure 137 compares the 2003 CRS program schedule with the 2004 CRS program schedule. Milestone C and Contingency Prototypes slip about nine months further into the future than what was planned in 2003. However, the remainder of the schedule is unchanged. This adjustment appears to make sense as this adjustment of Milestone C lines up with the start of full rate production. The funding that was planned for FY03 remains unchanged in the latest plan.

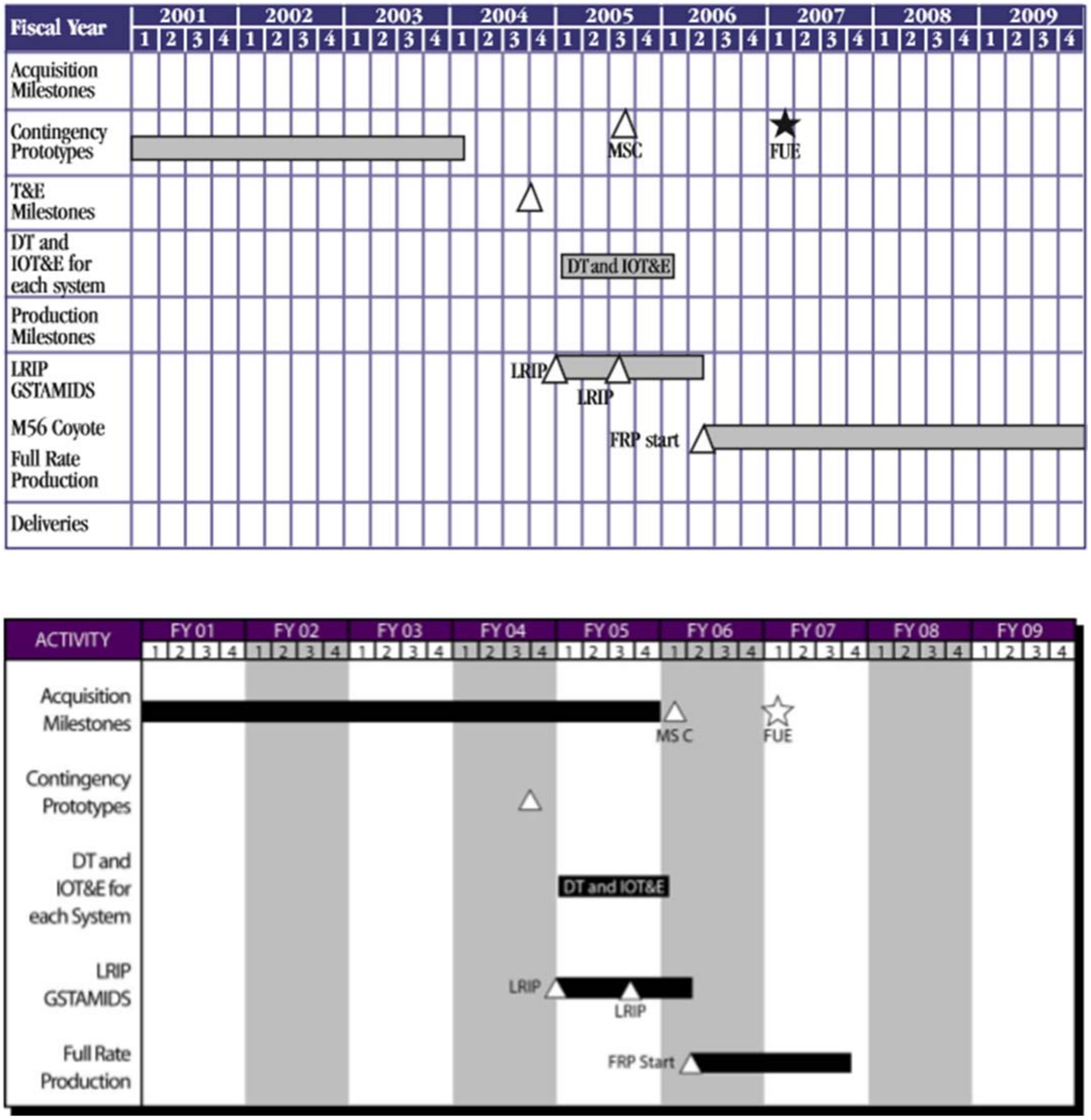
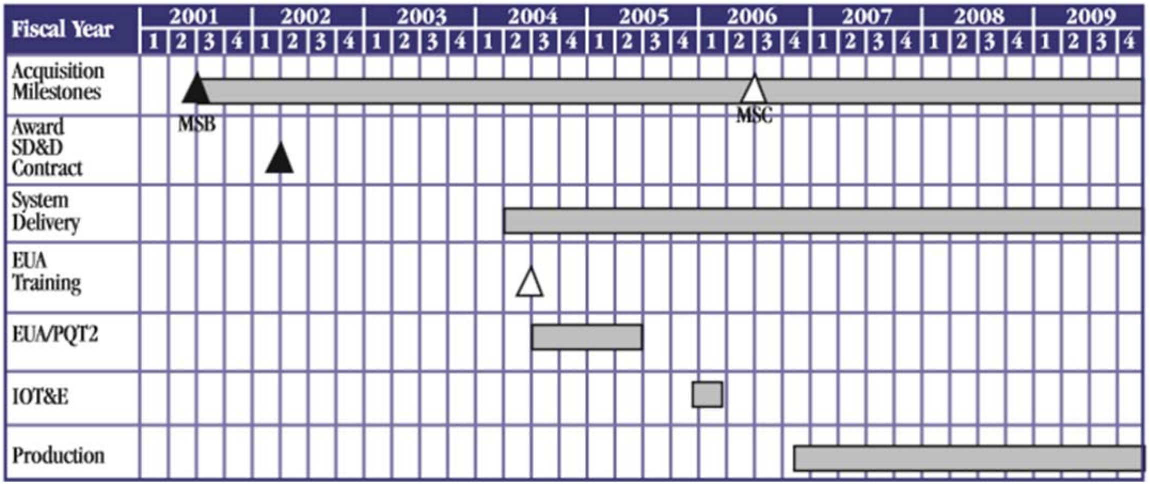


Figure 137. 2003 CRS Schedule Compared to 2004 CRS Schedule (from DOD, 2003, 2004)

d. MDARS from 2003 to 2004

In the past year, MDARS I/E have been reduced to simply MDARS. It appears that the interior program was cancelled and the emphasis is now on the exterior system. The system will still conduct interior patrols but the need for two separate systems that do almost the same task was redundant. The 2004 JRPMP reports that the first pre-production MDARS was delivered for testing and demonstration. In addition to security at military installations and depots, future modifications will target security at ports, ammunition supply points, forward operational bases (FOBs), and logistical bases (DOD, 2004). As previously mentioned, the MDARS program will work with the REDCAR program; this will support MDARS' intention of providing lethal and non-lethal responses on future models.

Figure 138 compares the MDARS-E schedule from 2003 with the MDARS schedule of 2004. The schedules are identical and there are no delays to what was planned the year prior. This further supports the claim that the MDARS-I program was dissolved and rolled into MDARS-E. The MDARS-I program did have a planned Milestone C in FY03. So unless it is in full rate production, and not discussed in the 2004 plan, the assumption is that MDARS-I has dissolved. The funding that was planned in the 2003 JRPMP for FY03 was unchanged in the past year.



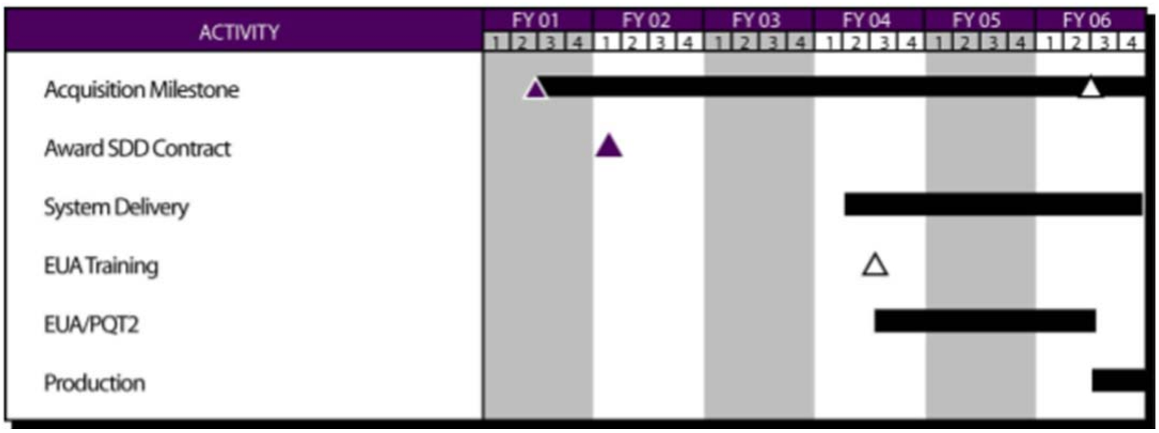


Figure 138. 2003 MDARS-E Schedule Compared to 2004 MDARS Schedule (from DOD, 2003, 2004)

e. RCSS from 2003 to 2004

The robotic combat support system (RCSS) program is experiencing significant change from what was reported last year. “As a result of the War on Terrorism and the ongoing activities in Afghanistan and Iraq, the need for a RCSS type asset was elevated to URGENT status” (DOD, 2004, p. 4-3). The Robotic Systems Joint Projects Office (RS JPO) recognized that the program schedule from 2003 would prevent the agency from filling this need for the warfighter. The RS JPO and user community decided jointly to change the program strategy to one where a commercial-off-the-shelf (COTS) system is acquired with fielding beginning in FY04. This option allowed the RS JPO to immediately procure and deliver systems to the users, particularly in Iraq. The COTS system is called the DOK-ING MV-IV and is a UGV that is produced in Croatia. “The DOK-ING MV-IV system is currently in use in Croatia (32 systems total). The MV-IV has a high reliability rate and has undergone multiple tests, all of which were successful” (DOD, 2004, p. 4-4). The system itself is manufactured in Croatia, but many of the subsystems are produced by companies like Sony and Caterpillar, which can support larger scale procurement.

Figure 139 compares the 2003 RCSS program schedule to the 2004 program schedule after the change in acquisition strategy. The key highlights include the removal of Milestone C from the 2004 schedule and the removal of a full rate production plan. The funding that was planned for FY03 is unchanged from what was planned a year earlier, but it appears that the program may go over budget based upon the reduced number of deliveries from 2003 to 2004. Table 54 compares the number of systems scheduled for delivery in each year. Overall, 111 less systems are set to be delivered in future years. Either the numbers demanded are down or the price of each unit is so much more expensive that they can only afford 24 total systems.

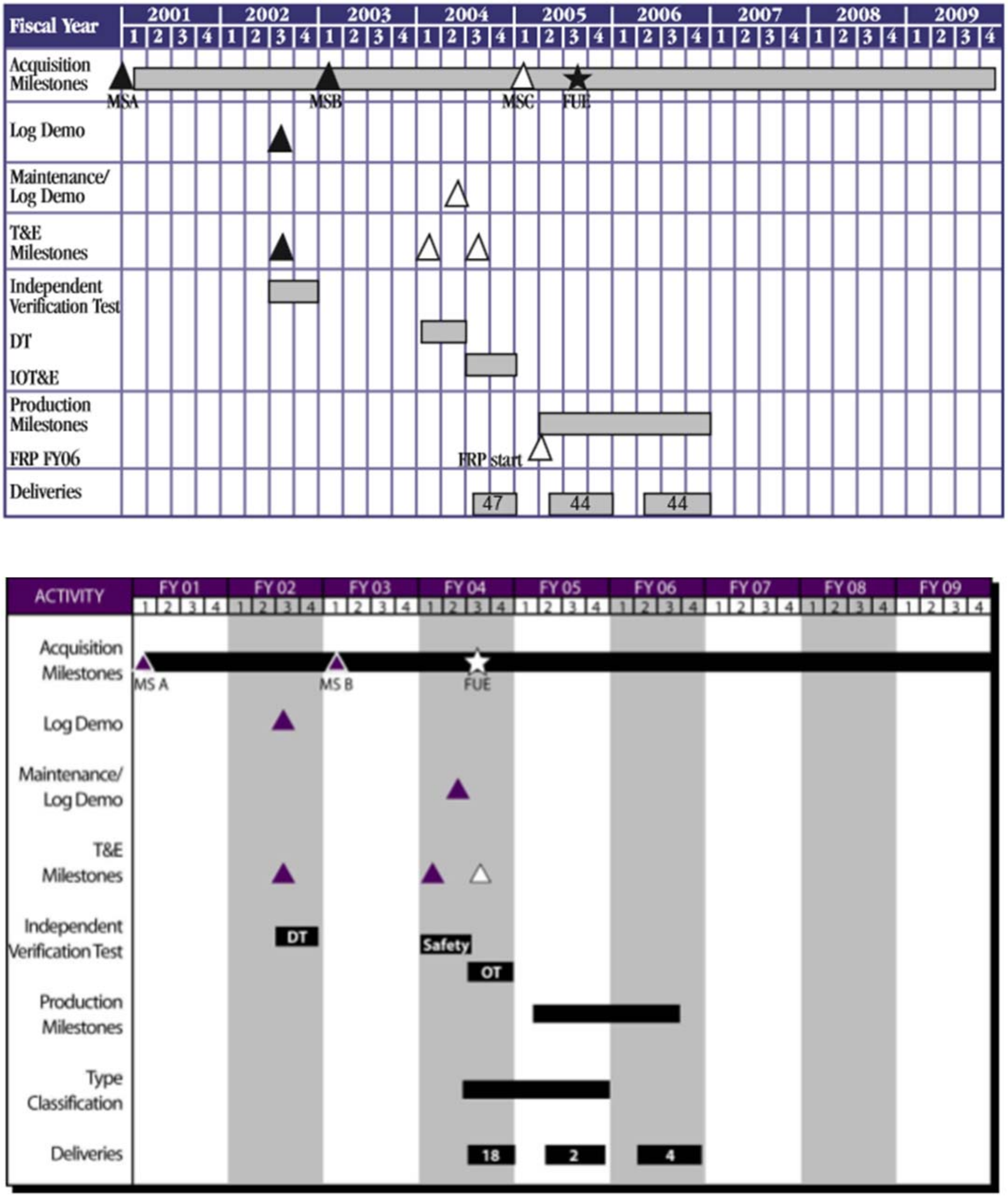


Figure 139. 2003 RCSS Schedule Compared to 2004 RCSS Schedule (from DOD, 2003, 2004)

Table 54. 2003 RCSS Systems to be Delivered Compared to 2004 Plan (from DOD, 2003, 2004)

	FY04	FY05	FY06	Total
Planned 2003	47	44	44	135
Planned 2004	18	2	4	24
Delta	29	42	40	111

f. IMP from 2003 to 2004

In the past year, a few notable events have occurred for the intelligent mobility program (IMP). First, the omnidirectional inspection system (ODIS) system completed its continental United States (CONUS) testing at various installations. Next, the underbellies of vehicles were successfully inspected with images appearing on a monitor for observation and finally, the next phase for the ODIS is to undergo testing in Iraq at vehicle check points, in a real-world mission. There are also 20 ODIS systems in production with delivery expected within the next year (DOD, 2004). Other research is ongoing within the program to improve UGV mobility overall, develop the marsupial concept, and to continue to measure payloads between various systems through the use of JAUS open architecture. The IMP schedule and funding from 2003 has not changed at all in the past year.

g. JAUS from 2003 to 2004

The 2004 JRP MP does an effective job of further explaining the joint architecture for unmanned systems (JAUS) program because it is very technical in nature. In short, "JAUS is a common language enabling internal and external communication between unmanned systems" (DOD, 2004, p. 4-6). The master plan then proceeds to list the five reasons that the JAUS program was developed: (1) To reduce overall life-cycle costs, (2) Because in early UGVs, each subsystem was built from scratch, (3) JAUS leads to performance gains, (4) Rapid technology advancements could not be inserted into existing UGVs, and (5) Issues preventing interoperability and multi-vehicle control (DOD, 2004). Each year the JAUS schedule adds more and more information, which is seen as a positive because so many stakeholders appear to support this program. Figure 140 compares the 2003 JAUS schedule to the 2004 JAUS schedule. The only slip to the schedule is Version 3.0 of Domain Model, which shifts one year further into the future. However, much more detail about program activity is listed with clear milestones presented. The program funding did not change in the past year.

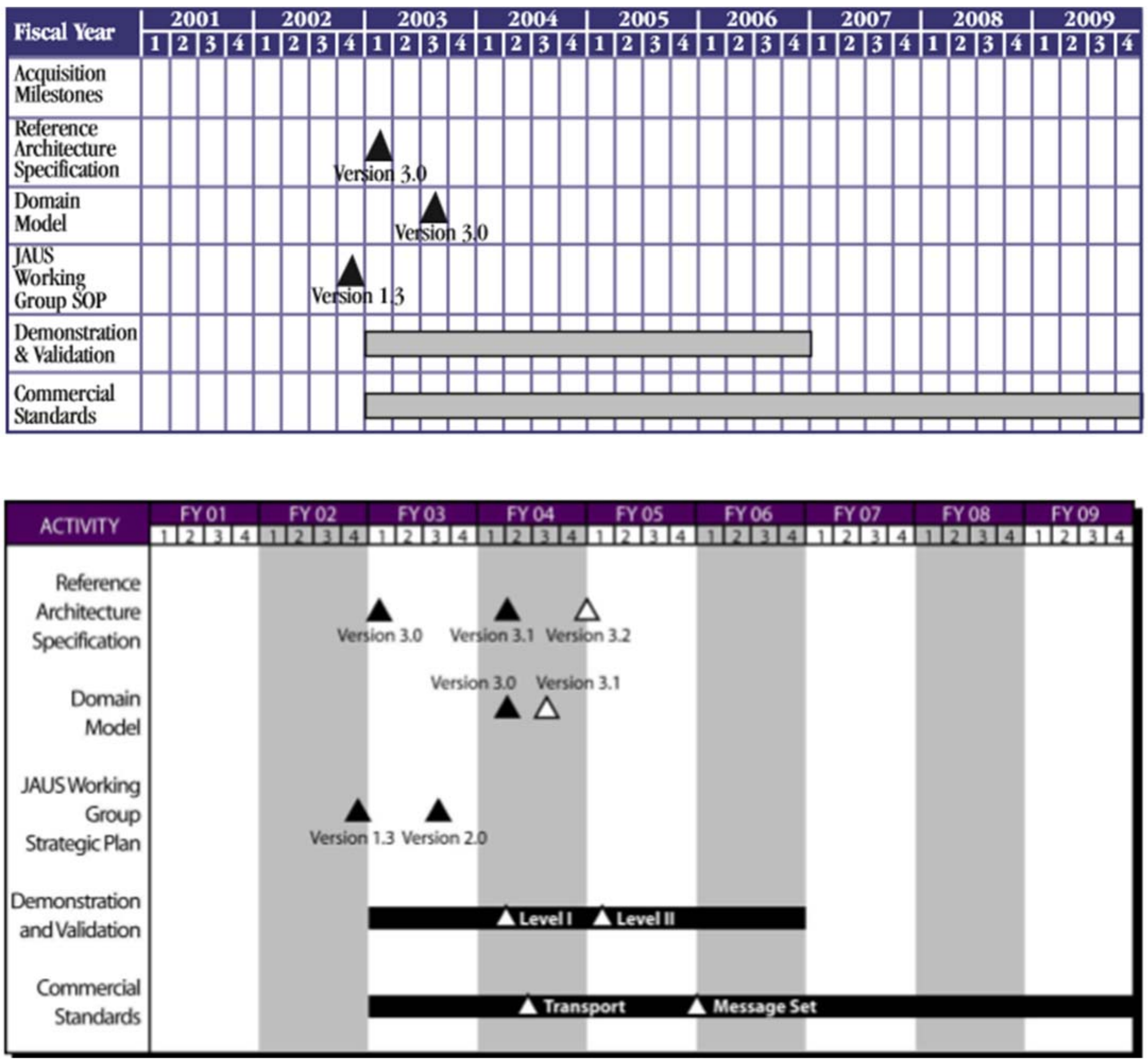


Figure 140. 2003 JAUS Schedule Compared to 2004 JAUS Schedule (from DOD, 2003, 2004)

h. RONS from 2003 to 2004

In the past year, a PC-based prototype, RONS, was produced and delivered for test and evaluation purposes. This is part of the RONS modernization program strategy. The 2004 JRPMP loosely addresses the S-Curve in regards to the RONS system. “Experience with the earlier RCT (Remote Control Transporter) suggested that the RONS would quickly fall behind the technology/capability ‘curve’ without a process in place to identify, develop (if necessary), test, and implement improvements in a timely manner” (DOD, 2004, p. 4-11). Based on this industry analysis, there are 26 ongoing improvements for the RONS program. This suggests exploitation of the current technology with incremental improvements until a major technological breakthrough occurs that makes this technology obsolete.

Table 55 compares RONS system procurement data from 2003 to 2004. Since the last JRPMP, 86 more systems have been delivered to users, and the overall objective shows an increase by seven systems. The Navy and Army also both increased their overall objective, and, according to this plan, only three more total systems will be delivered to the Army; this will conclude the planned fielding of this system. It appears that upgrades to the system will continue to go out to the force as they are completed.

Table 55. 2003 RONS System Procurement Compared to 2004 RONS Procurement (from DOD, 2003, 2004)

2003	Army	Navy	Air Force	Marines	Totals
Delivered	49	28	75	2	154
On Order	9	0	30	6	45
Planned	5	0	3	0	8
Objective	67	28	112	29	236

2004	Army	Navy	Air Force	Marines	Totals
Delivered	66	33	112	29	240
On Order	3	0	0	0	3
Objective	69	33	112	29	243

In 2003, the JRP funded $800,000 towards RONS RDT&E. In 2004, this number rose to $2.1 million. This was not forecasted in the 2003 plan, but there is a FY04 forecast of $3.3 million RDT&E funding for RONS. This funding is also shared with the EOD MTRS program which includes the Talon and PackBot systems. The detailed breakdown of funding is under the MTRS section.

i. MTRS from 2003 to 2004

The approach to the MTRS program is an interesting strategy. The plan calls for the delivery of a core system immediately to EOD technicians in Afghanistan and Iraq and a plan to continually upgrade the systems based on user feedback. The DOD demonstrates progressive thinking in the open architecture approach it is taking. "The vehicle will incorporate industry standard communication ports to enable interoperability with various sensors in future system upgrades that will enhance the reconnaissance capabilities of the MTRS" (DOD, 2004 p. 5-12). This is representative of the success of the JAUS and NGEODRCV programs that promote interoperability and transfer of new technology between systems.

Foster-Miller, Inc. and iRobot Corporation were both awarded contracts based on best value. In the past year, each vendor delivered a performance specifications verification model (PVSM) of their proposed systems. After testing of the PSVM, a decision will be made to continue with each contractor or not (DOD, 2004).

Figure 141 compares the 2003 MTRS schedule with the 2004 MTRS schedule. All activities from the 2003 figure remain on schedule and the 2004 schedule goes into greater detail, giving a confident impression that production will begin in FY05. The funding that was planned for this program in the 2003 JRPMP is unchanged, but it is now understood that this funding is shared with the continuous improvement program from the RONS program. The specific allocation to the MTRS program in FY03 was $1 million, which is about 47% of the allocated funds. The FY04 planned funding for RONS and MTRS is $3.3 million; based on the FY03 allocation we predict that $1.57 million will go to MTRS and $1.73 million to RONS.

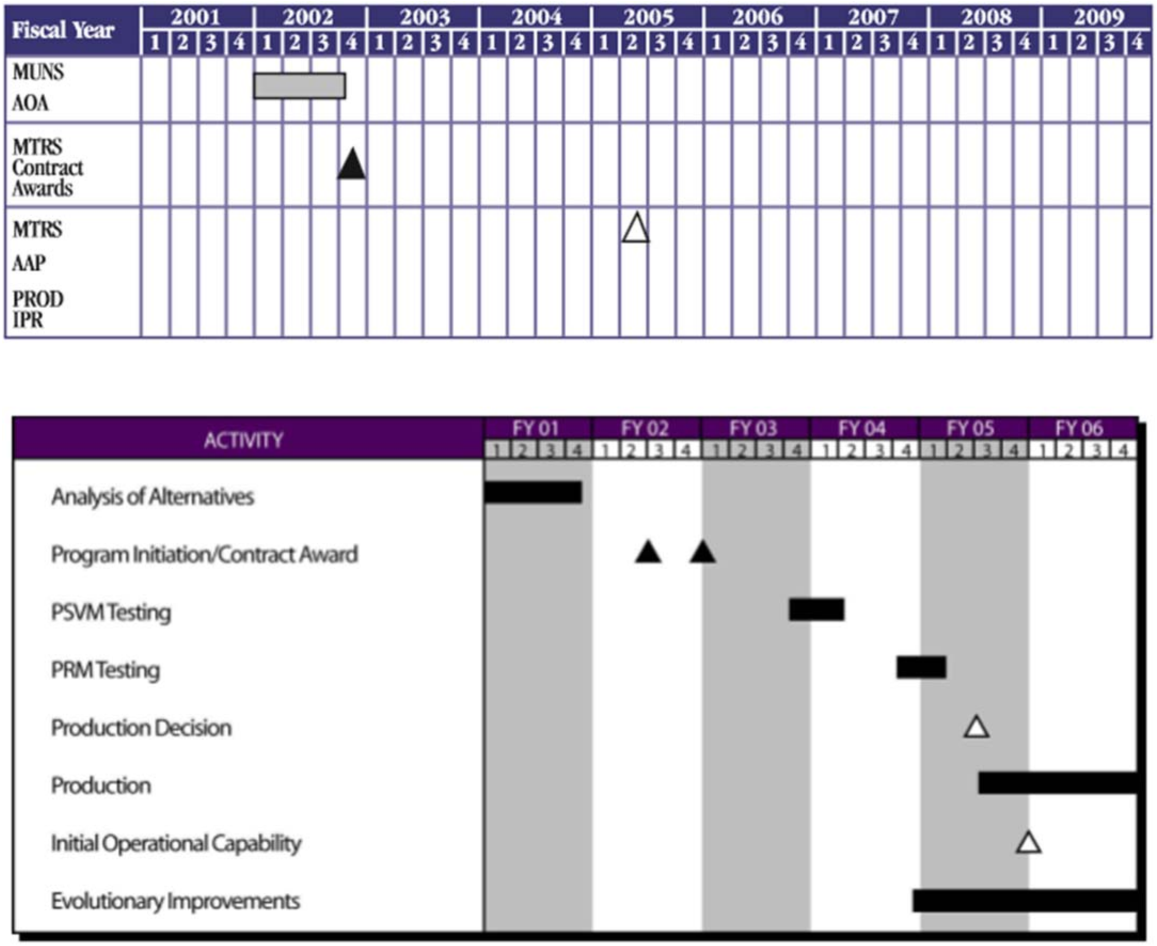


Figure 141. 2003 MTRS Schedule Compared to 2004 MTRS Schedule (from DOD, 2003, 2004)

j. RF ATD from 2003 to 2004

The 2004 JRPMP presents interesting updates regarding the RF ATD program. From a hardware standpoint, the dismount OCU was designed and developed and the system/software integration onto the Stryker and experimental unmanned vehicle (XUV) platforms was completed (DOD, 2004). This is tangible progress and is positive news for the FCS program. From a test and evaluation standpoint, the Stryker conducted high-speed following on an improved road using LOS. The XUV conducted low-speed following of dismounted troops across field terrain (DOD, 2004). A convoy mission was conducted with vehicles in the program and the multifunction utility/logistics equipment (MULE) conducted a dismounted support mission. In both missions, the systems demonstrated a TRL (Technology Readiness Level) of 6 (DOD, 2004). According to the DOD 5000.2-R, this means a

> system/subsystem model or prototype demonstration in a relevant environment: Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. It also represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment. (DOD, 2002, p. 204)

This is an aggressive technology development program that could lead to an extremely useful capability to the DOD in the near future.

Figure 142 lays out the RF ATD demonstration schedule for each mission that is planned under this program. This schedule looks similar to the DEMO II schedule that was presented in earlier master plans. The RF ATD overall program schedule remains unchanged from what was presented in 2003 and no program funding details are presented in 2004.

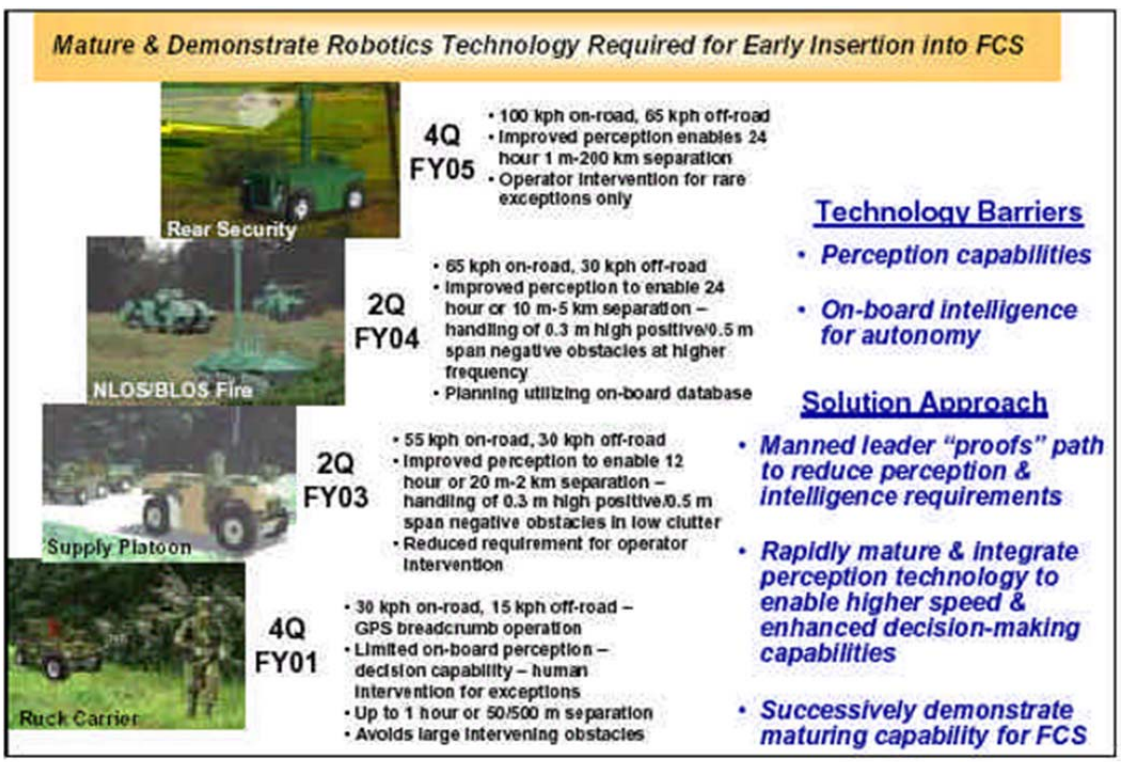


Figure 142. RF ATD Program Schedule (from DOD, 2004)

k. CAT ATD from 2003 to 2004

The CAT ATD program's primary purpose is to develop technology in support of the FCS program. The main thrust is to develop a system on a Bradley infantry fighting vehicle (IFV) or Stryker vehicle that allows the vehicle to be manned by two operators while conducting a host of military missions. "Technologies to be investigated include both traditional SMI technologies (e.g., helmet-mounted displays, head trackers, panoramic displays, speech recognition, 3D audio, etc.) and robotic technologies (e.g., intelligent driving decision aids, semi-autonomous driving, automated route planning, etc.)" (DOD, 2004, p. 6-10). This program appears to be high in the design and concept phase of the project. This capability is also advanced, and the software development for this program must be a significant undertaking. Effectively managing this program will require a schedule with oversight of numerous activities, which was lacking in the first schedule published in 2003. Figure 143 compares the CAT ATD schedule from 2003 to the current schedule in the 2004 JRPMP. The current schedule provides much more detail for the listed activities and the naming convention from last year's schedule has changed noticeably. Success in this program could change the way the United States fights future wars. No funding is presented for this program in 2004.

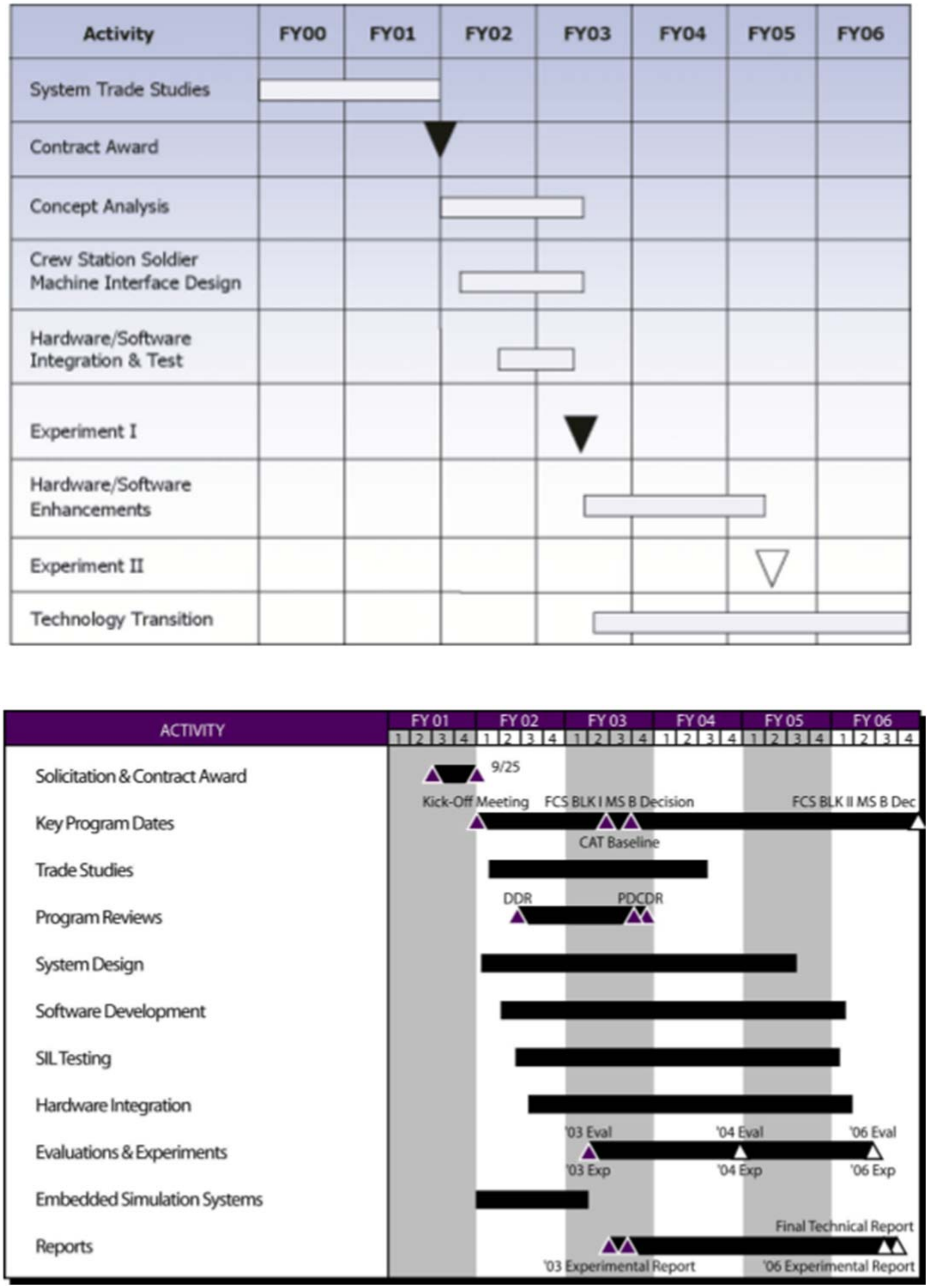


Figure 143. 2003 CAT ATD Compared to 2004 CAT ATD Schedule (from DOD, 2003, 2004)

l. NGEODRCV from 2003 to 2004

There are no specific accomplishments to report on this program in the last year. However, Figure 144 compares the program schedule from 2003 with the 2004 program schedule. The 2003 program schedule went out to 2009 and displayed Milestone B, while the 2004 schedule only displays out to 2006 and does not display any events beyond Milestone A. More activity detail is provided in the 2004 schedule, but there are no firm markers to indicate hard dates. Table 56 compares the 2003 funding with the 2004 funding. The actual funding for FY03 in the 2004 master plan is greater than what was planned the year prior. This is because the technical support working group (TSWG) funding is up by half a million dollars more than what was originally planned. The $2 million provided by JRP is actually OSD physical security equipment money and was planned for FY03 in the 2003 master plan but was not represented on that year's NGEODRCV funding table.

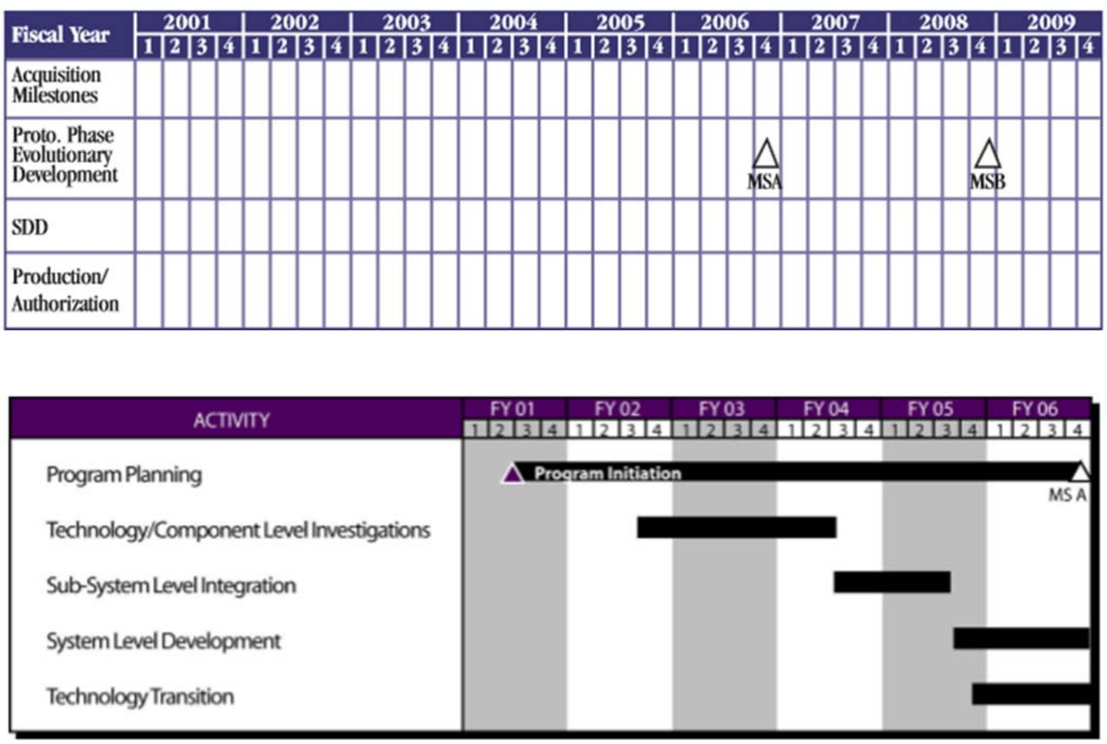


Figure 144. 2003 NGEODRCV Schedule Compared to 2004 NGEODRCV Schedule (from DOD, 2003, 2004)

Table 56. 2003 NGEODRCV Funding Compared to 2004 NGEODRCV Funding (from DOD, 2003, 2004)

SOURCE	FY02	FY03
TSWG	0.5	.5
JRP	0.3	0.0[a]
OGA	2.0	1.0
TOTAL	2.8	3.5

Source	FY03	FY04
TSWG	1.0	0.5
JRP	2.0[a]	2.0
OGA	1.0	1.5
Total	4.0	4.0

m. ART STO (Armed Robotic Technology, Science & Technology Objective) 2004

ART STO, the first of three new programs in the 2004 JRPMP aims to "develop, integrate, and demonstrate the technology required to achieve advanced autonomous capabilities for the Objective Force, specifically the ARV (Armed Robotic Vehicle)" (DOD, 2004, p. 6-11). Essentially, the goal of the program is to continue to develop advanced autonomous capabilities so that the ARV can be an effective combat vehicle. The 2004 JRPMP states that by 2006 the STO will demonstrate TRL 5 and by 2008 will demonstrate TRL 6 (DOD, 2004). Up to this point, highly autonomous operations in unstructured environments has been the biggest challenge for UGVs and while this program has good intentions, the technology may not support this goal anytime in the near future. The master plan does not say when this technology may be ready. Figure 145 displays the first program schedule for ART STO, with no firm milestones presented for the program at this time. Additionally, no funding for this program is presented in the master plan.

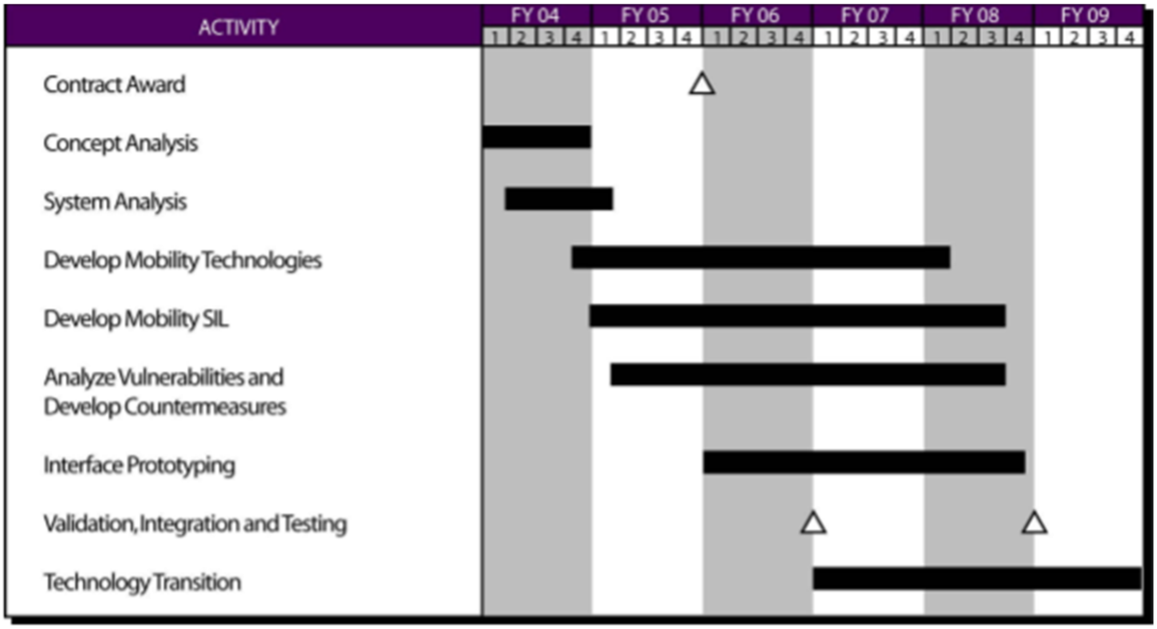


Figure 145. ART STO Program Schedule (from DOD, 2004)

n. HRI STO (Human-Robot Interaction, Science & Technology Objective) 2004

HRI STO is the second new program in the 2004 JRPMP. In short, this program aims at developing common user interfaces for unmanned ground and air systems. The idea is that a Soldier should be able to recognize an unmanned system control unit and have a general idea of how to use it, even without any experience on the system. Part of this push is to allow more unmanned systems into the force that are not military occupational specialty (MOS) specific. Essentially, Soldiers take time from their regular jobs to operate unmanned systems. This problem is, however, further compounded when the Soldier must spend time trying to figure out how to work the controls for each new system. HRI STO aims to create commonality. Figure 146 is the first HRI STO program schedule presented in 2004. Much like the ART STO, there are not a lot of firm dates on the schedule at this time. No funding for this program appears in the master plan.

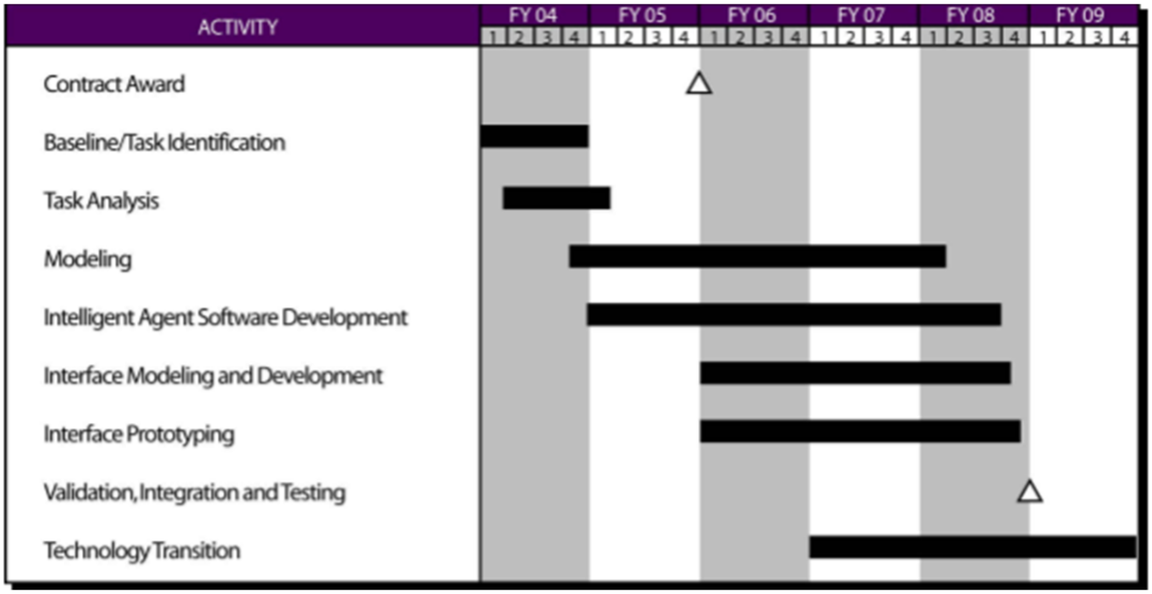


Figure 146. HRI STO Program Schedule (from DOD, 2004)

o. NUSE2 (National Unmanned Systems Experimentation Environment) 2004

NUSE2 is the third and final new program presented in the 2004 JRPMP. NUSE2, a continuation of the robotic acquisition through virtual environments & networked simulations (RAVENS) program, concluded in 2003. While RAVENS was a beneficial program, it did not include many key stakeholders involved in NUSE2. This program harnesses all military unmanned communities (air, ground, surface, and underwater), academia, industry, and other R&D efforts (DOD, 2004). The ultimate goal of this program is to publish standards that are accepted across the unmanned system's community and result in the following benefits: reduced program cost, reduced risk, accurate schedules, focused R&D efforts, interoperability, prevented stove piping, conserved resources, and leveraged technology to the end user incrementally as technology matures (DOD, 2004). All of these efforts can lead to a virtuous cycle where the warfighter constantly receives the latest technology, accomplished at an affordable price. This program does not have FY03 funding, but there is $3.7 million in planned funding for FY04.

p. Conclusion

The UGV program's increasing demand for systems due to the conflicts in the Balkans, Afghanistan, and Iraq proves for interesting shifts. The warfighters appear to favor UGVs, and Congress acknowledges this by appropriating more money to the UGV program. The war in Iraq and increased IED threats are also shaping acquisition strategies that put commercial systems in the hands of warfighters more quickly, but with what appears to be less planning on the back end.

Year after year, the UGV program grows in number of programs and in the amount of money allocated to the programs. From 2003 to 2004, the program schedules and funding appeared to be the most stable compared to any other years. There are some assumptions why this is happening. First, the war in Iraq is generating more funding to programs, which allows program managers to accomplish what was planned. Second, the severity of being engaged in multiple conflicts has led to stricter program oversight which results in staying on schedule and on budget. Third, in some cases, the programs are looking for commercial solutions, and the schedules are not actively managed for the time being while alternate methods to rapidly field new equipment are explored. It could also be a combination of these factors or others that have not been considered.

This is the last version of what is known as the master plan. From here forward, the DOD produced documents called road maps. The research concludes in 2004 due to the drastic change in reporting between a master plan and a road map. Road maps do not display individual program schedules and they do not include program funding tables.

4. Summary from 2001 to 2004

From 2001 to 2004, the UGV program funding is presented as concept and technology development (CTD; Figure 147), and engineering and manufacturing development (EMD; Figure 148) funding. The CTD and EMD categories were compared against each other and is shown in Figure 149. In the period covered, funding rises in both categories each year except for FY02 when CTD funding decreases by about $1 million. This can be attributed to new programs added to the portfolio, higher prioritization of UGVs in the DOD budget, and increased demand from users as the U.S. military engaged in combat on multiple fronts.

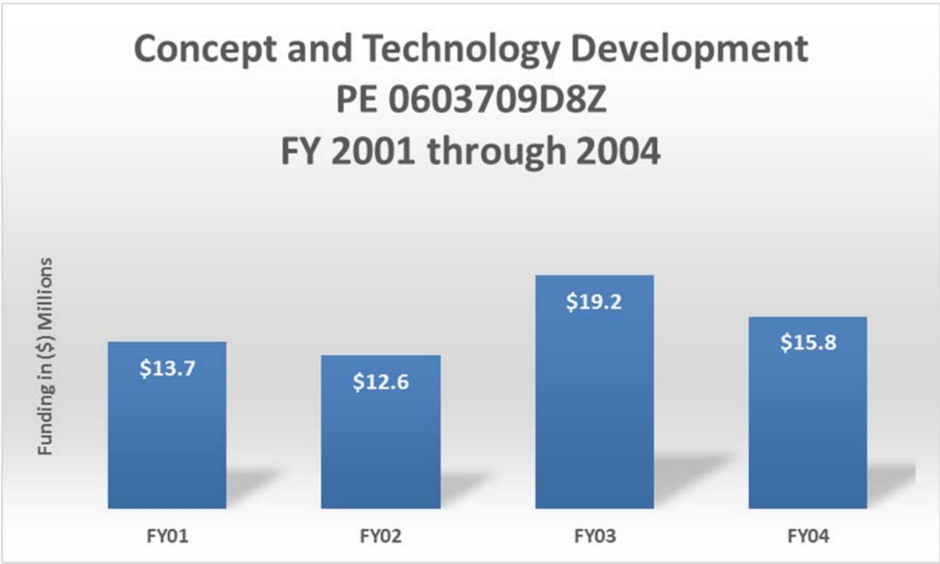


Figure 147. Concept and Technology Development (CTD) Funding Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

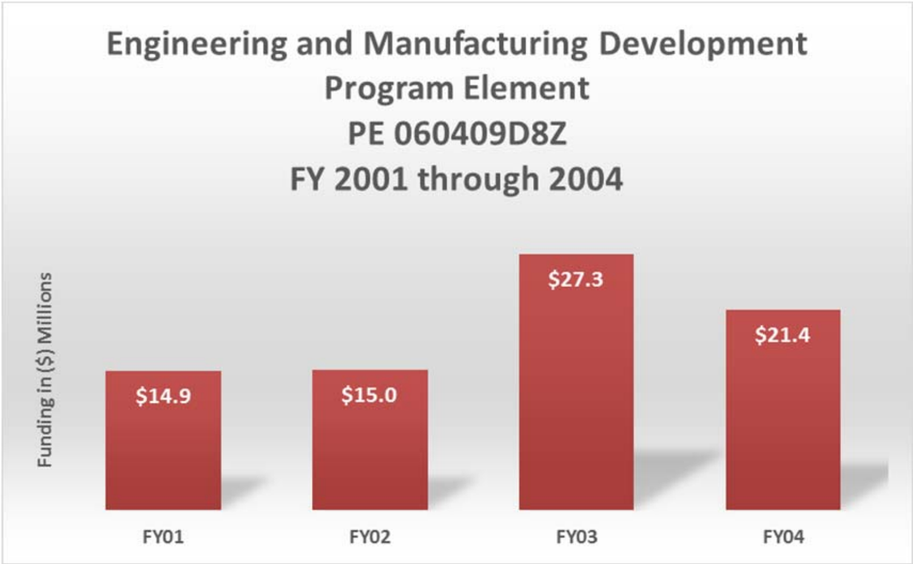


Figure 148. Engineering and Manufacturing Development Funding Comparison–2004 (after DOD, 2001, 2003, 2004)

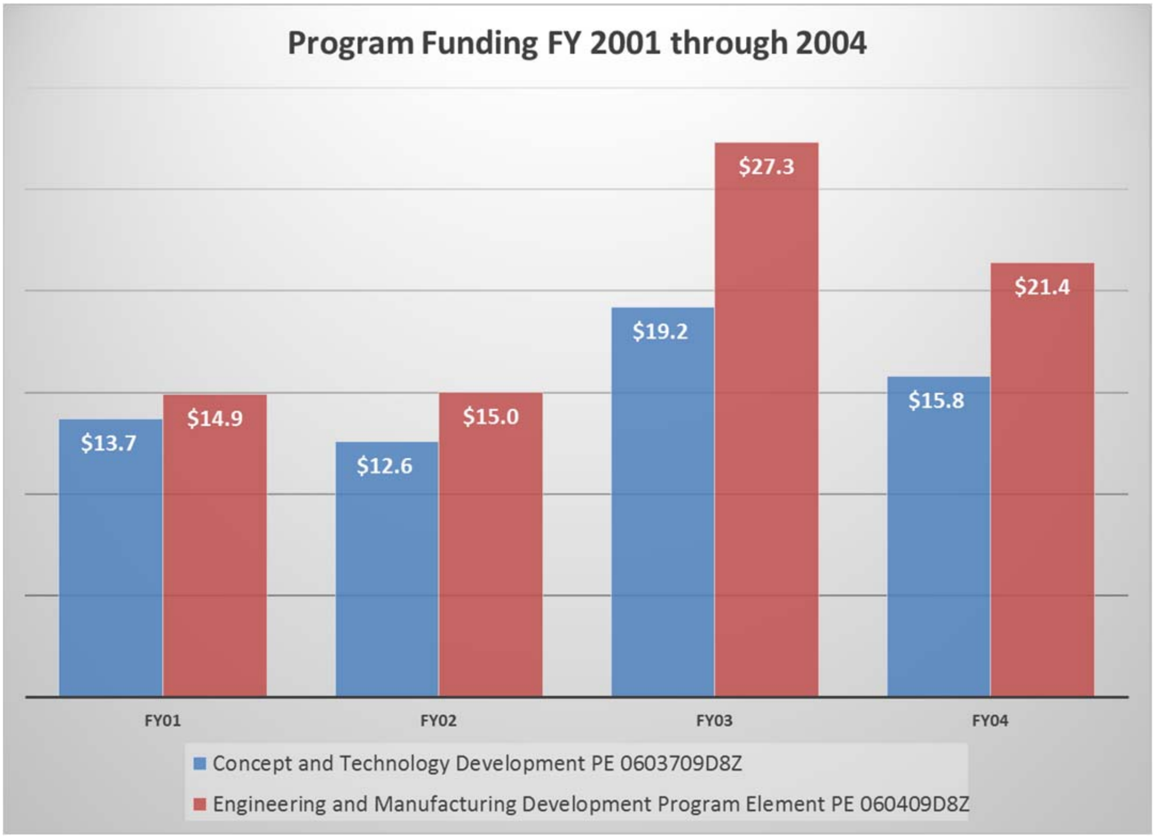
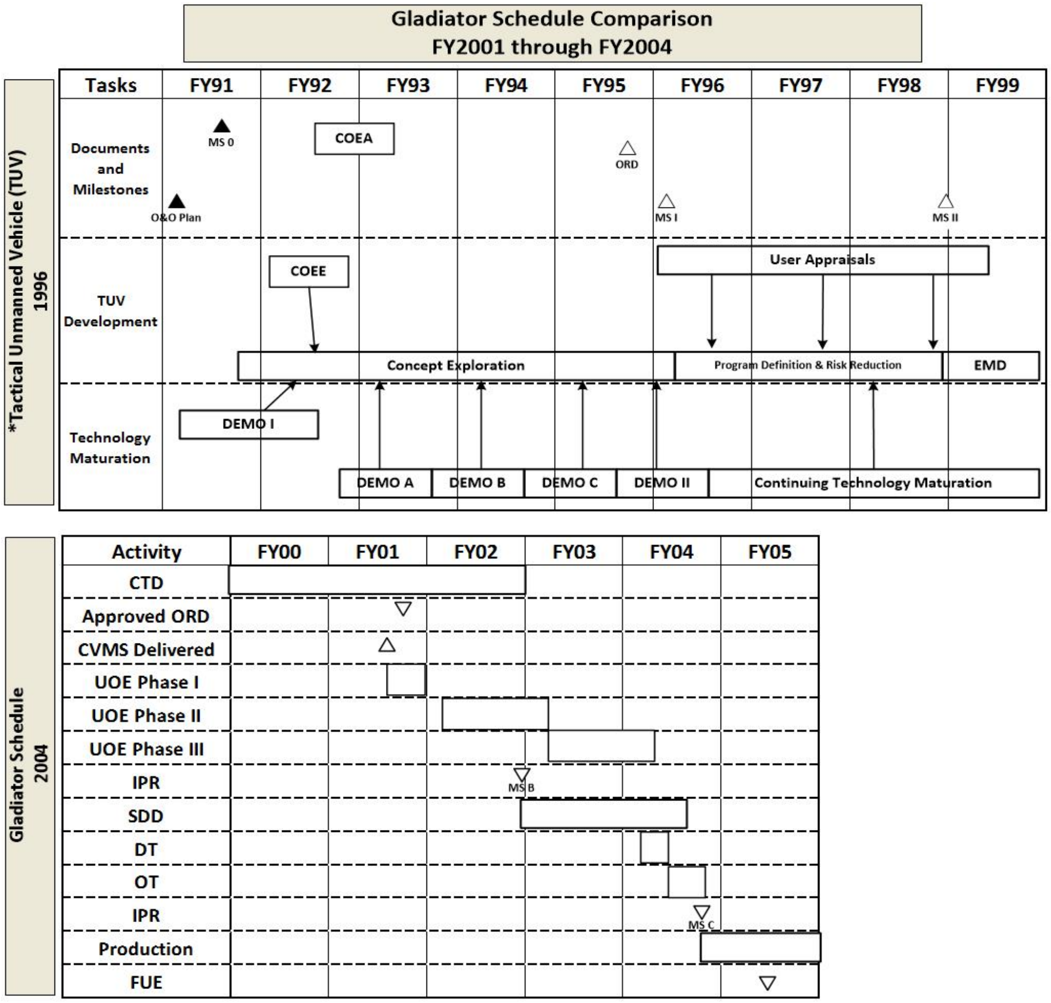


Figure 149. Concept and Technology Development and Engineering Manufacturing Development Funding Comparison (after DOD, 2001, 2003, 2004)

a. *FTUV/TUGV from 2001 to 2004*

There was a gap in TUGV schedules from 1996 to 2003; when both schedules are compared, the outlook for the program does not look positive, as depicted in Figure 150. Milestone II/B shifts from FY98 to FY02 and Milestone C is planned for FY04. The positive aspect from this report is that the schedule did not change from 2003 to 2004, which is the first time that a TUGV schedule experienced no slippage. In Figure 151, the TUGV/Gladiator funding is significantly reduced compared to years past, but in 2004 the funding rises substantially. The USMC endorses the program completely and believes the technology is mature enough for the system to accomplish capabilities never achieved before in a TUGV program.



*Tactical Unmanned Ground Vehicle (TUGV) was renamed Tactical Unmanned Vehicle (TUV) in 1996, Family of Tactical Unmanned Vehicles(FTUV) in 2000, and Gladiator in 2001.
**No TUGV/FTUV/Gladiator schedule was produced in 2001, the last known schedule (1996), was used for this schedule.

Figure 150. TUV/Gladiator Schedule Comparison with Schedule Slippage 1996–2004 (after DOD, 1996, 2001, 2003, 2004)

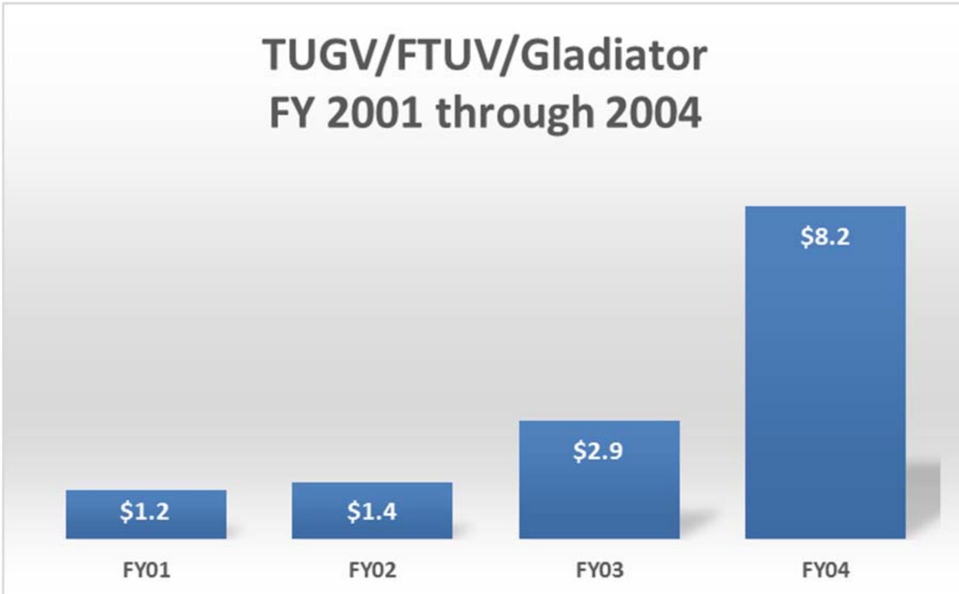
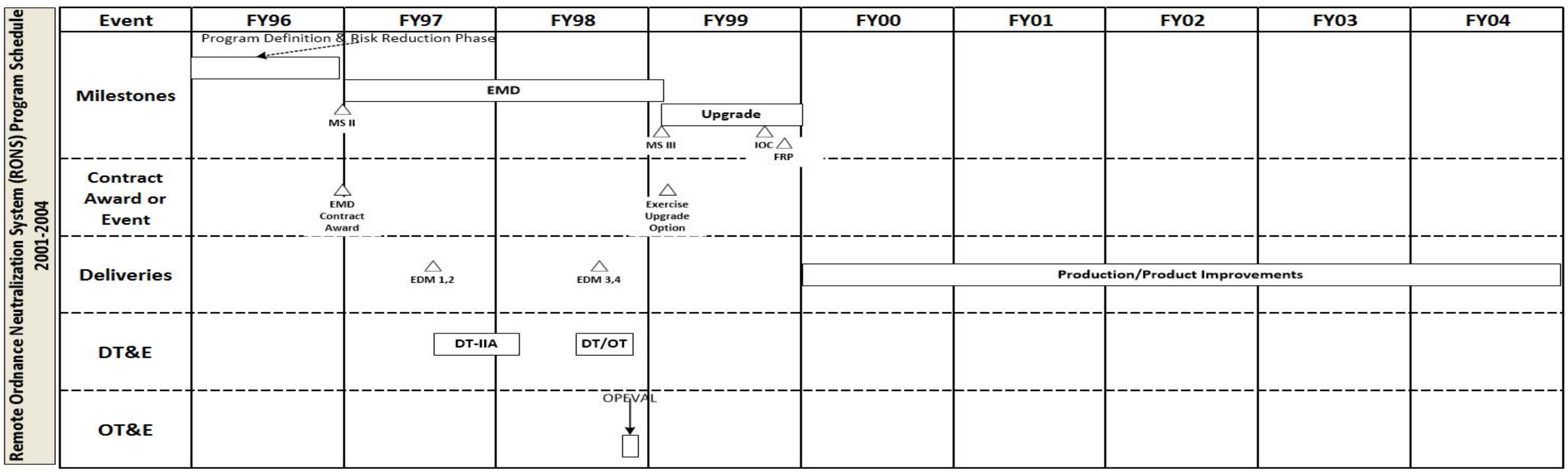


Figure 151. TUGV/FTUV/Gladiator Funding Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

b. RONS from 2001 to 2004

The RONS program is probably the most successful program in the time period covered in this research. The program achieved full rate production in FY99 and units are available for use by the warfighter. The schedule in Figure 152 depicts the transition to sustainment and continuous improvements to the system since its fielding. The funding in Figure 153 appears sporadic, but is this way based on the number of systems procured each year. FY02 and FY04 are years where more systems are purchased. FY01 and FY03 are likely years where there is limited procurement or where R&D is ongoing in support of improvements to the fielded increment.

Remote Ordnance Neutralization System (RONS) Schedule Comparison
FY2001 through FY2004



2001	Army	Navy	Air Force	Marines	Totals
Delivered	49	28	30	0	107
Planned	49	28	84	11	172
Objective	98	56	114	11	279

2003	Army	Navy	Air Force	Marines	Totals
Delivered	49	28	75	2	154
On Order	9	0	30	6	45
Planned	5	0	3	0	8
Objective	67	28	112	29	236

2004	Army	Navy	Air Force	Marines	Totals
Delivered	66	33	112	29	240
On Order	3	0	0	0	3
Objective	69	33	112	29	243

***RONS achieved Milestone III, Initial Operational Capability (IOC) and began Full Rate Production (FRP) in FY99.**
Table depicts number of systems produced in 2001, 2003, and 2004.

Figure 152. ROND/RONS Schedule Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

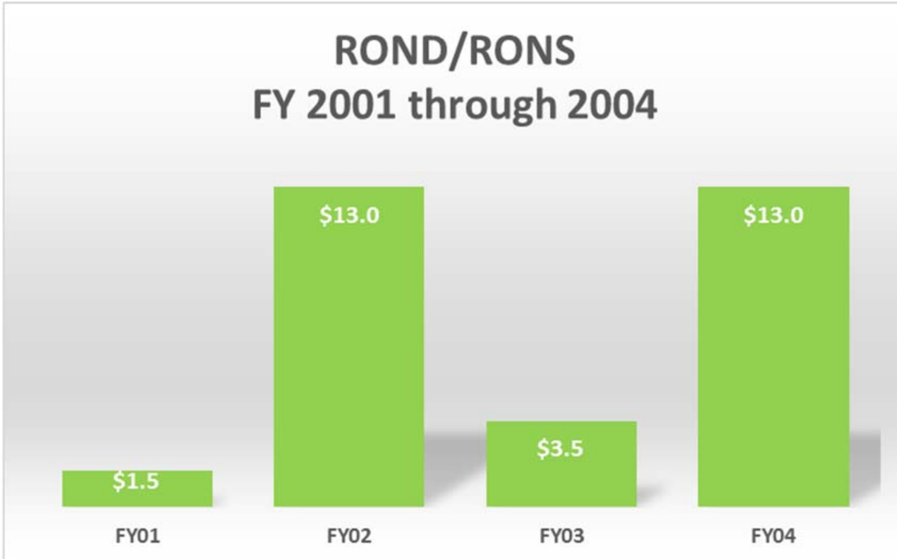
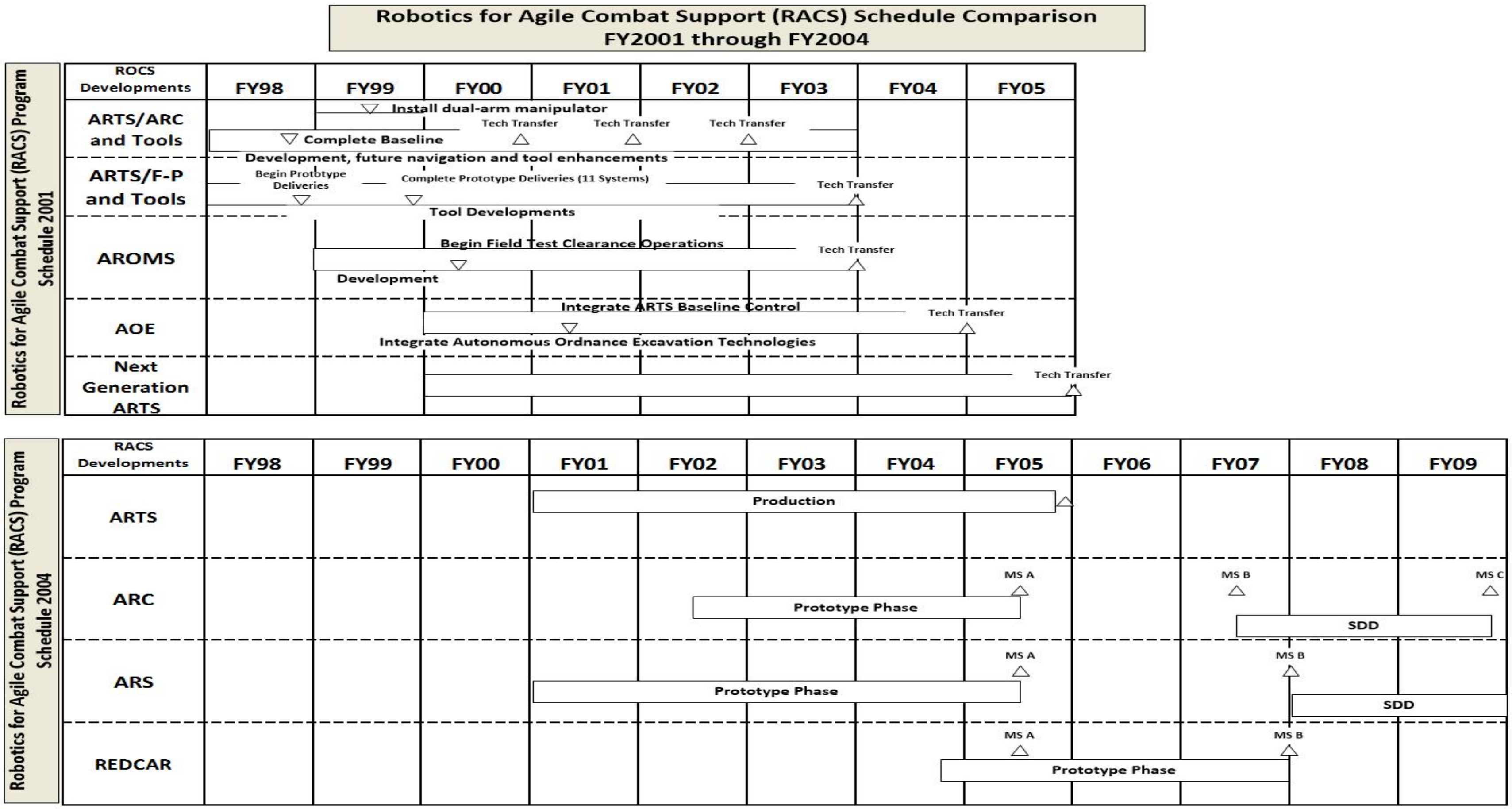


Figure 153. ROND/RONS Funding Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

c. ROCS/RACS from 2001 to 2004

Until 2004 the RACS schedule was difficult to decipher, but was determined that the ARTS achieved full rate production in FY01. The other two systems depicted in the 2001 schedule continue to slip further into the future. In the 2004 master plan, there are three systems under RACS; all plan to achieve Milestone A in FY05, which is at least a two-year slippage when compared to the 2001 master plan. Earlier RACS schedules do not clearly display common acquisition milestones, so in some cases, the milestones are assumed. Logically, the schedule has slipped, considering no events were planned for FY05 in the 2001 master plan as depicted in Figure 154. RACS funding is inconsistent over the past few years. The RACS program grew in size in the period analyzed and is now four programs under RACS, each demanding independent funding. The ARTS system is in the procurement phase and is more costly than R&D. This may help explain the large increase in funding to the program in FY04 as depicted in Figure 155.



***Rapid Runway Repair (RRR) was renamed Robotic Excavation Vehicle (REV) in 1993, Robotic Ordnance Clearing System (ROCS) in 2000, and Robotics for Agile Combat Support (RACS) in 2001.**

****RACS Program consists of: All-Purpose Robotic Transport System (ARTS), Active Range Ordnance Mapping System (AROMS), Automated Ordnance Excavator (AOE), Active Range Clearance (ARC), Advanced Robotic Systems (ARS), and Remote Detection, Challenge and Response System (REDCAR)**

Figure 154. ROCS/RACS Schedule Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

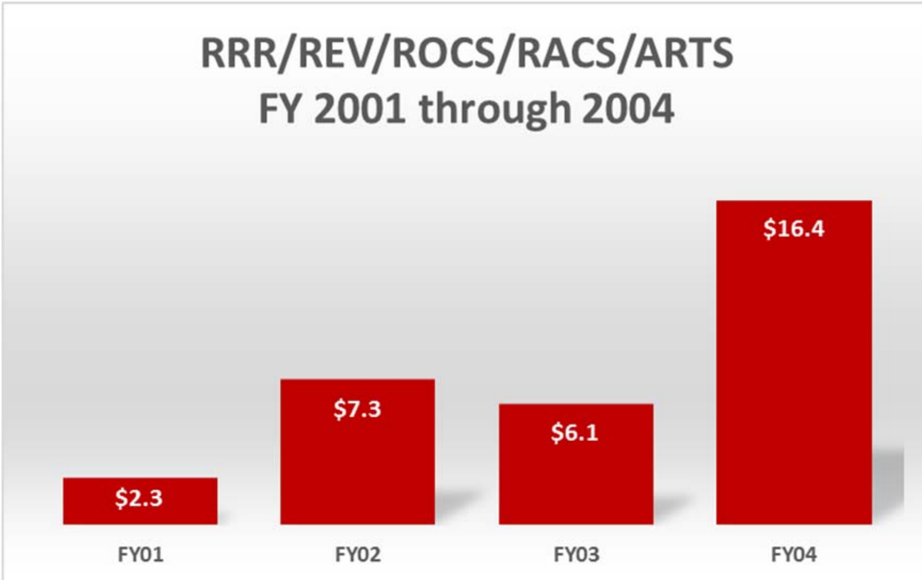
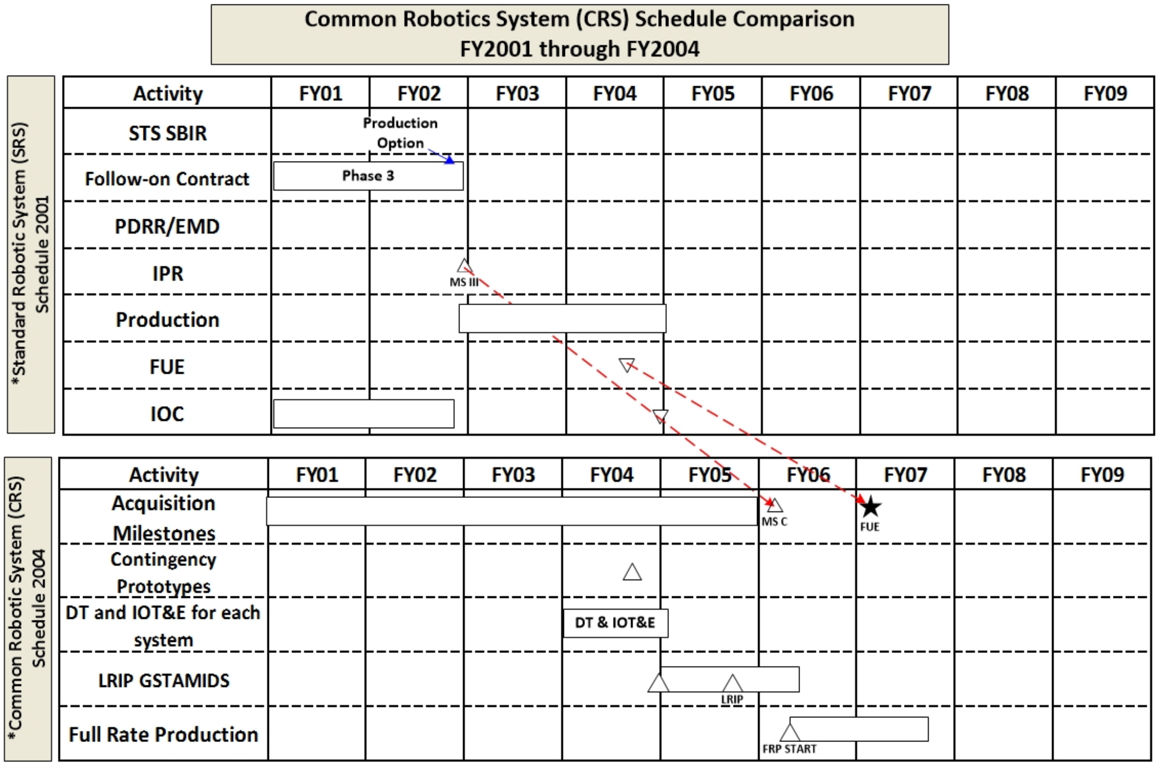


Figure 155. RRR/REV/ROCS/ARTS Funding Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

d. VT/CRS from 2001 to 2004

CRS became the top program during the conflict in Bosnia, which was supposed to accelerate the schedule to deliver more systems to users at a faster pace. Instead, Milestone C shifts almost four years further into the future between 2001 and 2004, which makes the priority of this program questionable, as depicted in Figure 156. The funding fluctuates significantly during this time period, but in FY01 and FY03 the program receives a generous portion of the UGV budget as depicted in Figure 157. This may be the result of a formal fielding of older system variants, but is not reported in the master plan, so this is an assumption.



***Vehicle Teleoperation Capability (VTC) was renamed Vehicle Teleoperation (VT) Program in 2000, Standard Robotics System (SRS) in 2001, and Common Robotic System (CRS) in 2003.**

Figure 156. EVTC/VTC/VT/SRS/CRS Schedule Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

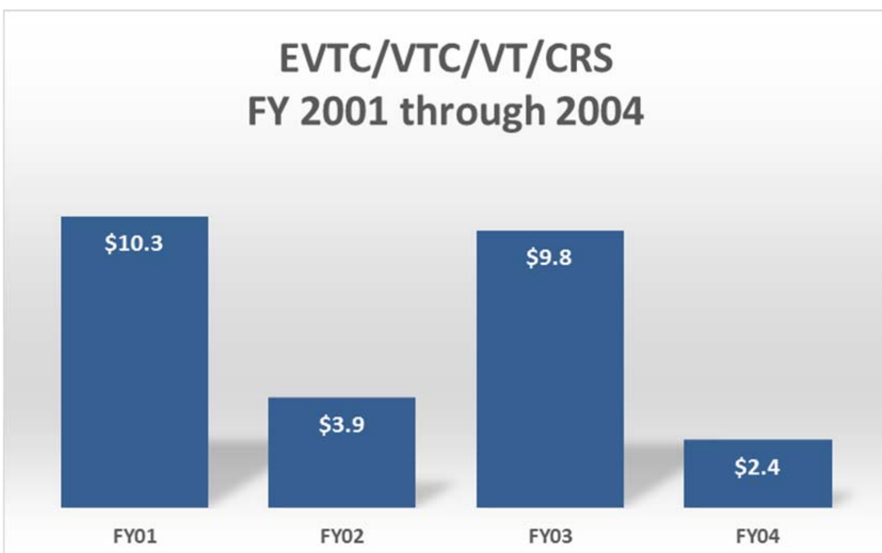


Figure 157. EVTC/VTC/VT/SRS/CRS Funding Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

e. MDARS-E/I from 2001 to 2004

In Figure 158 MDARS-E generally stays on schedule during the period analyzed. From 2001 to 2004, Milestone III shifts one year further into the future than originally planned. In a four-year span it is not poor performance for cutting-edge technology.

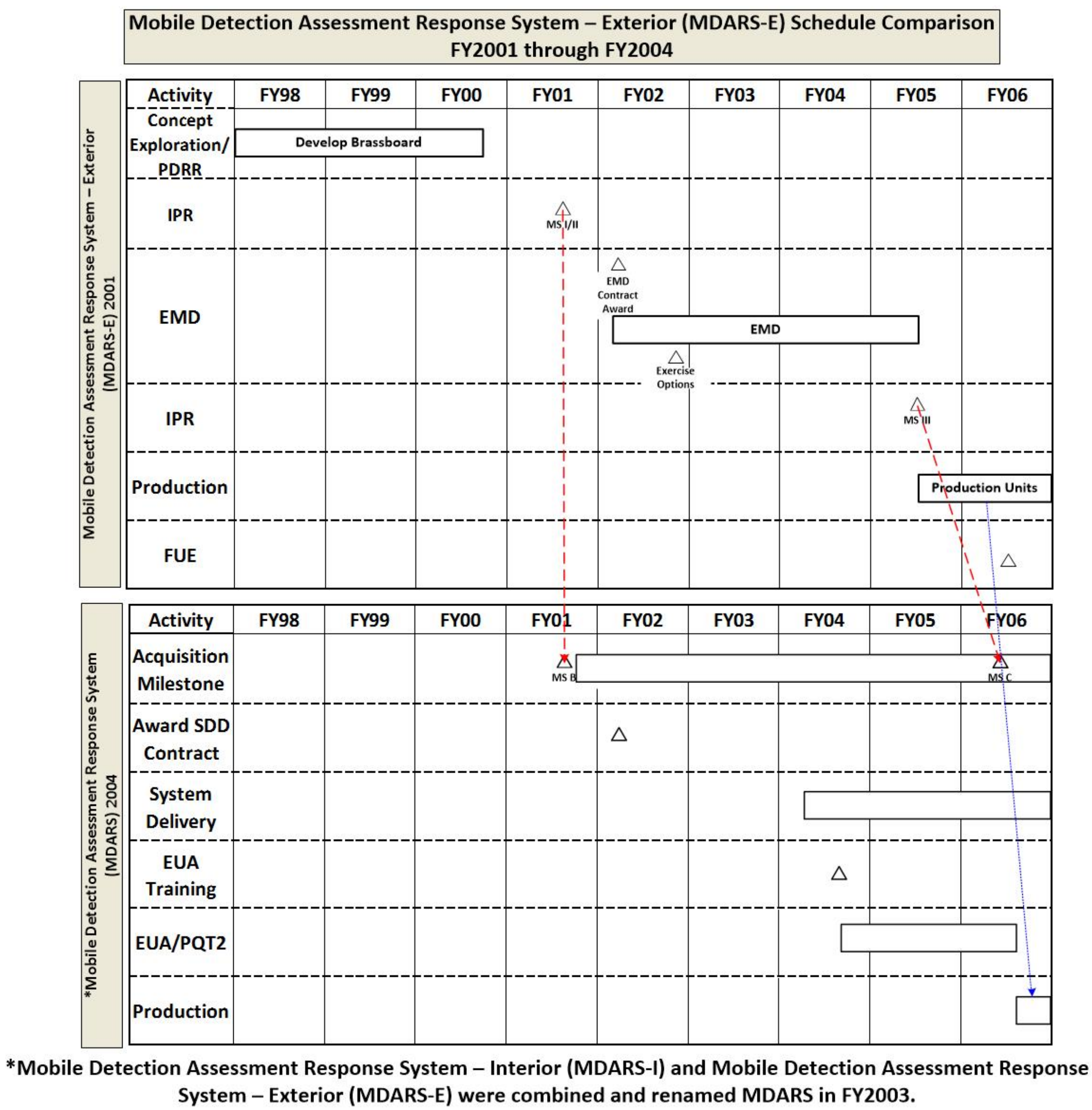


Figure 158. MDARS-E Schedule Comparison 2001–2004 (after DOD, 2001, 2003, 2004)

MDARS-I does not display the same success as the exterior program. From 2001 to 2004 the schedule experiences significant shifts into the future, as depicted in Figure 159. Milestone II/B moves from FY98 in the 2001 JRPMP to FY01 in the 2004 JRPMP. Milestone III/C shifts from FY02 to FY06. These are significant shifts that are not explained and cannot be good for the overall program. This program is based on vehicles conducting autonomous security within a facility, and the technology may have been too advanced at the time, causing the program to update the schedule to align with a more likely time frame in which the technology would be mature.

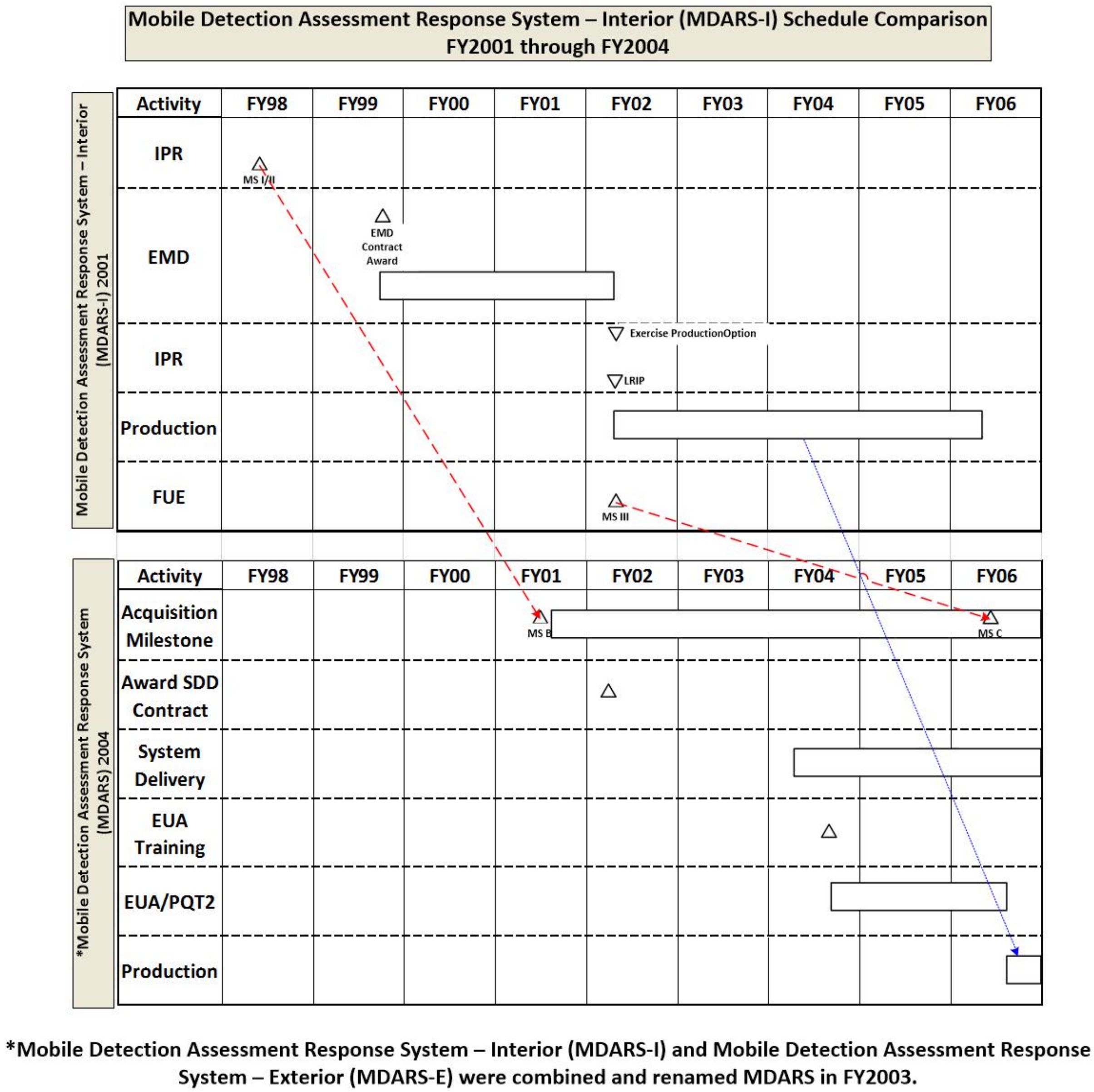


Figure 159. MDARS-I Schedule Comparison Illustrates Milestone Slippage 2001–2004 (after DOD, 2001, 2003, 2004)

f. DOD and UGV Funding Comparison 2001–2004

During the years measured, the correlation between the DOD budget and the UGV budget is 0.67, but a correlation of 0.80 or higher would be more significant. The UGV budget in Figure 160 fluctuates substantially, even with military conflicts on multiple fronts. Again, this may be an indicator that UGVs are not high on the U.S. military list of priorities. Undoubtedly, UGVs are seen as important assets; however, they are still not fully integrated into the force and possibly face resistance from leaders that prefer a human being on the ground to accomplish the mission.

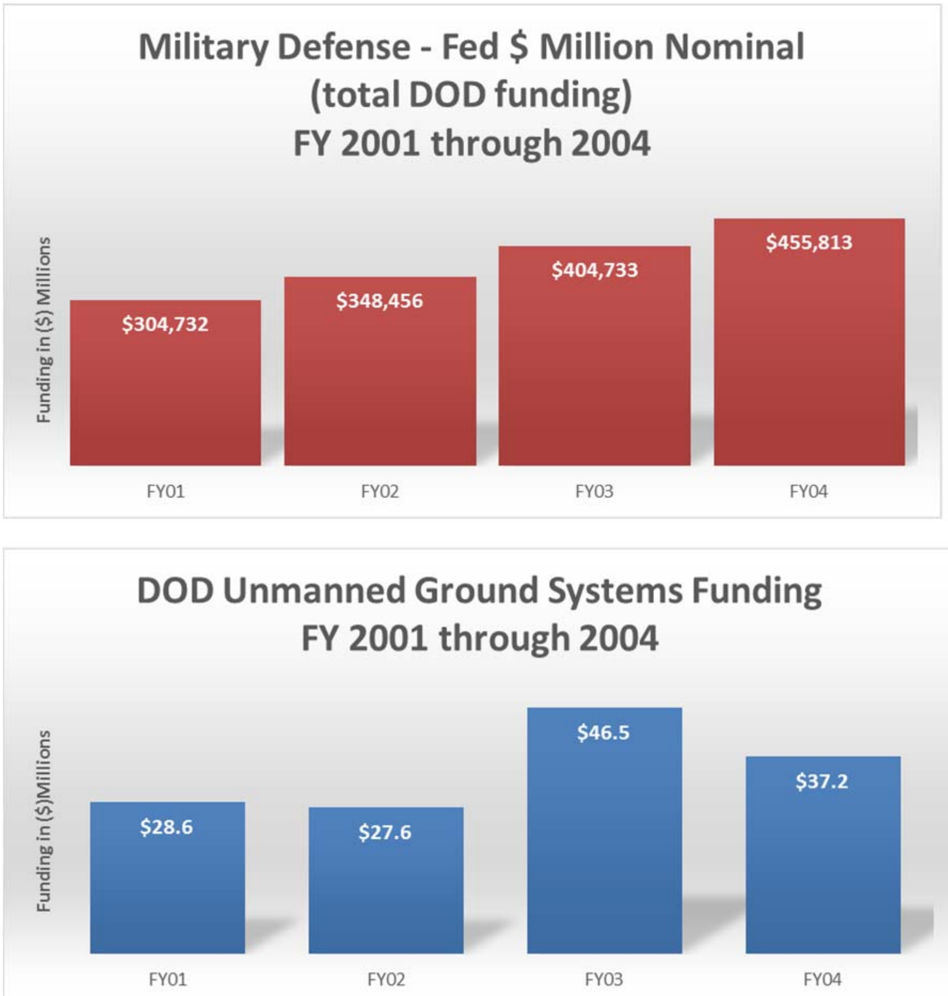


Figure 160. DOD and UGV Funding Comparison 2001–2004 (after DOD, 2001, 2003, 2004; usgovernmentspending.com, n.d.)

D. SUMMARY OF MASTER PLANS FROM 1991–2004

The goal of this section is to summarize all of the data presented in the first 14 years of UGVs within the DOD. Figure 161 depicts UGV funding from 1990 to 2005 and provides a snapshot showing the challenges that create hardships for UGV programs in the period examined. From 1990 to 1998, UGV funding for category 6.3 (advanced technology development) fluctuated but generally rose. In 1999, 6.3 funding dropped significantly but 6.4 (advanced component development and prototypes) started and overall UGV funding generally rose, but not at a rate that indicates high prioritization within the DOD. The year 1999 is also the same year that the RONS program achieved Milestone C and began full rate production. One key observation about funding during the R&D phase is that regardless of whether funding is cut or not, programs still experienced schedule slippage.

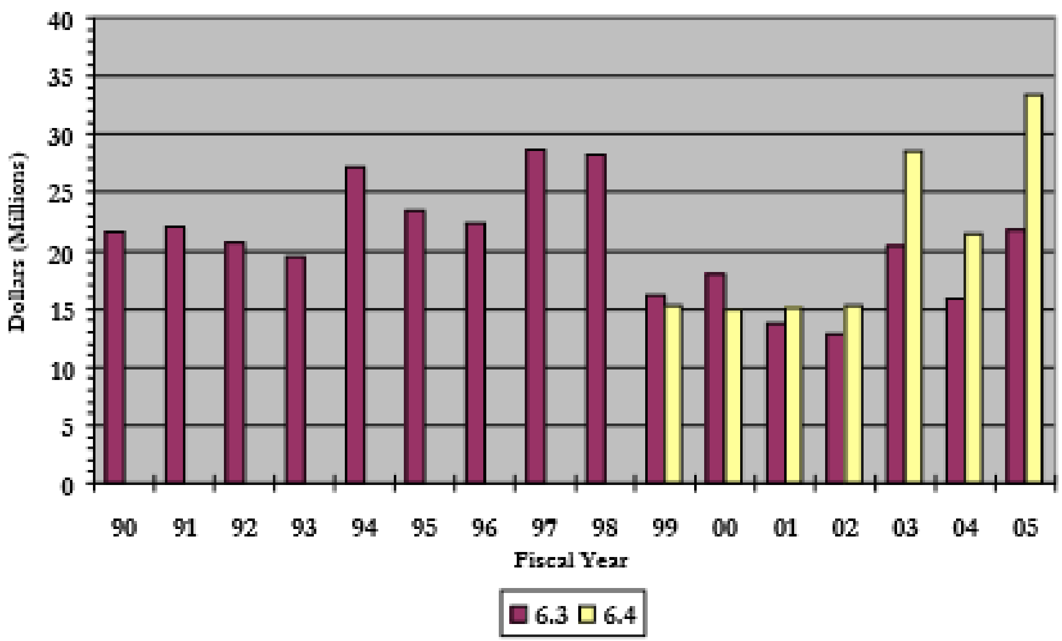


Figure 161. UGV Funding 1990–2005 (from DOD, 2005)

1. TUGV from 1991 to 2004

The first program summarized is the tactical unmanned ground vehicle (TUGV) program. This program was first presented in the 1991 master plan and continues through the 2004 master plan as depicted in Figure 162. Overall, the program does not appear to be a success. A quick glance of the first TUGV schedule in the 1991 master plan shows Milestone III/C planned for FY98. This milestone shifted further into the future in almost every other master plan examined. The schedule presented in the 2004 plan shows a Milestone C IPR planned for FY04. In 14 years, no TUGVs achieved Milestone C or full rate production.

This program is not necessarily a failure; many technologies and advancements developed from this program were transferred to other programs in the portfolio. Simply stated, the RSTA mission still remains extremely complex and difficult for UGVs. To successfully complete the RSTA mission, UGVs must function autonomously in unstructured environments. Achieving full autonomy requires a major technological breakthrough and it is difficult to predict when this may occur. Programs similar to the DEMO I, II, and III programs that are sponsored by DARPA and other advanced research agencies create the best opportunities for this breakthrough to happen.

In the early years, a significant portion of UGV funding went to this program. The researchers' assumption is that the lack of delivery of systems to end-users hurt the program. The program constantly pushed the system, but users did not appear to demand the TUGV for Infantry or RSTA missions. This is an advanced technology that will likely face resistance from leaders and warfighters upon integration. Integration is the best way to gain acceptance and will lead to the pull factors that allow new technologies to flourish. Ultimately, this is a repetitive cycle of push, pull, integration, and adaptation. The overall TUGV program funding from 1991 to 2004 is shown in Figure 163.

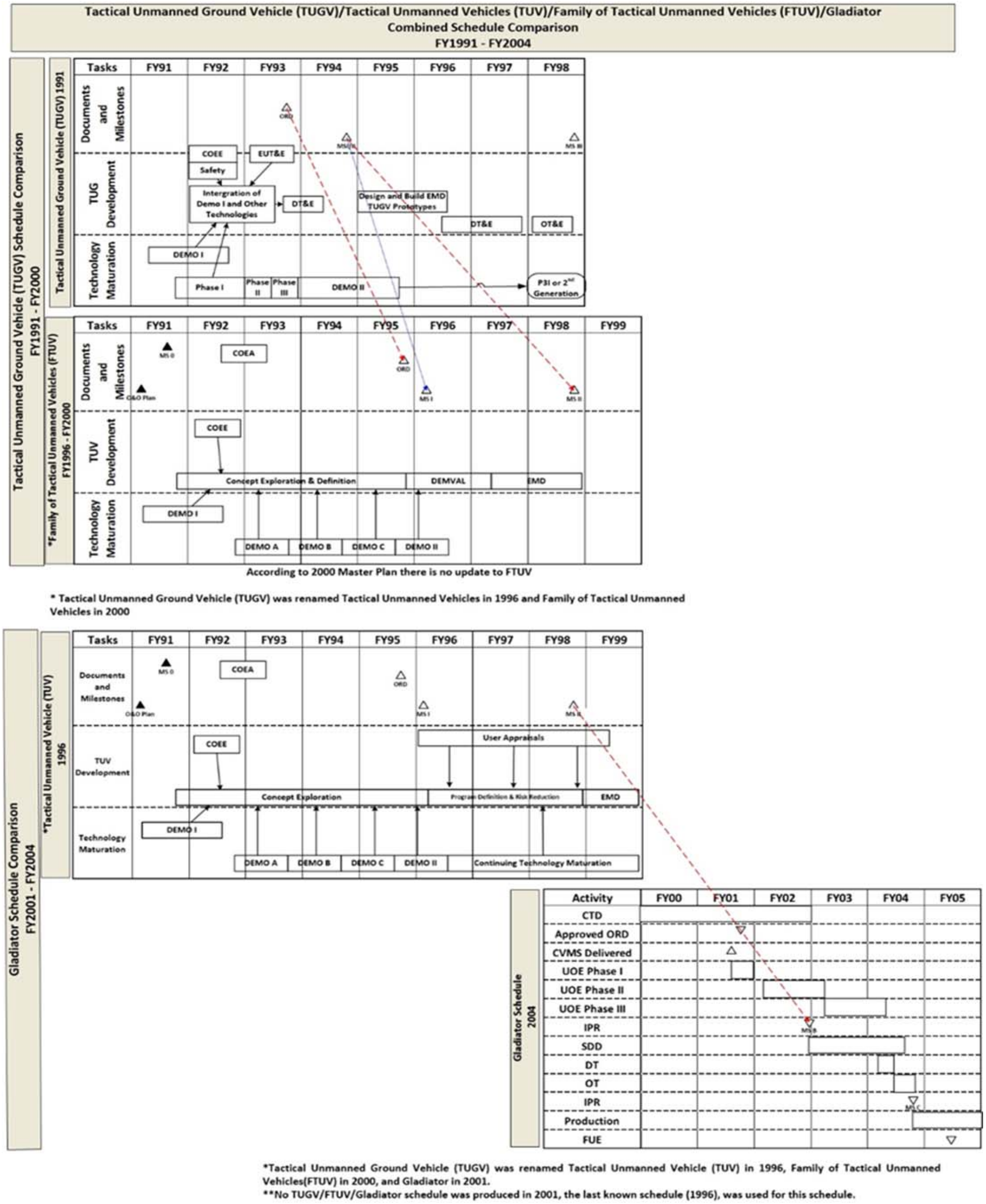


Figure 162. TUGV/TUV/FTUV/Gladiator Schedule Comparison Illustrates Milestone Slippage 1991–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2000, 2001, 2003, 2004)

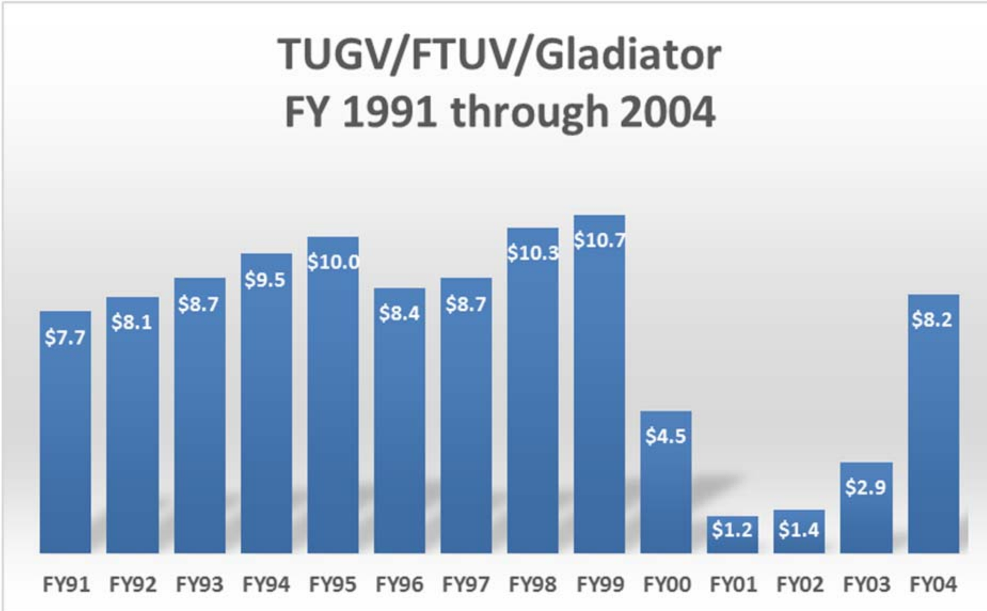


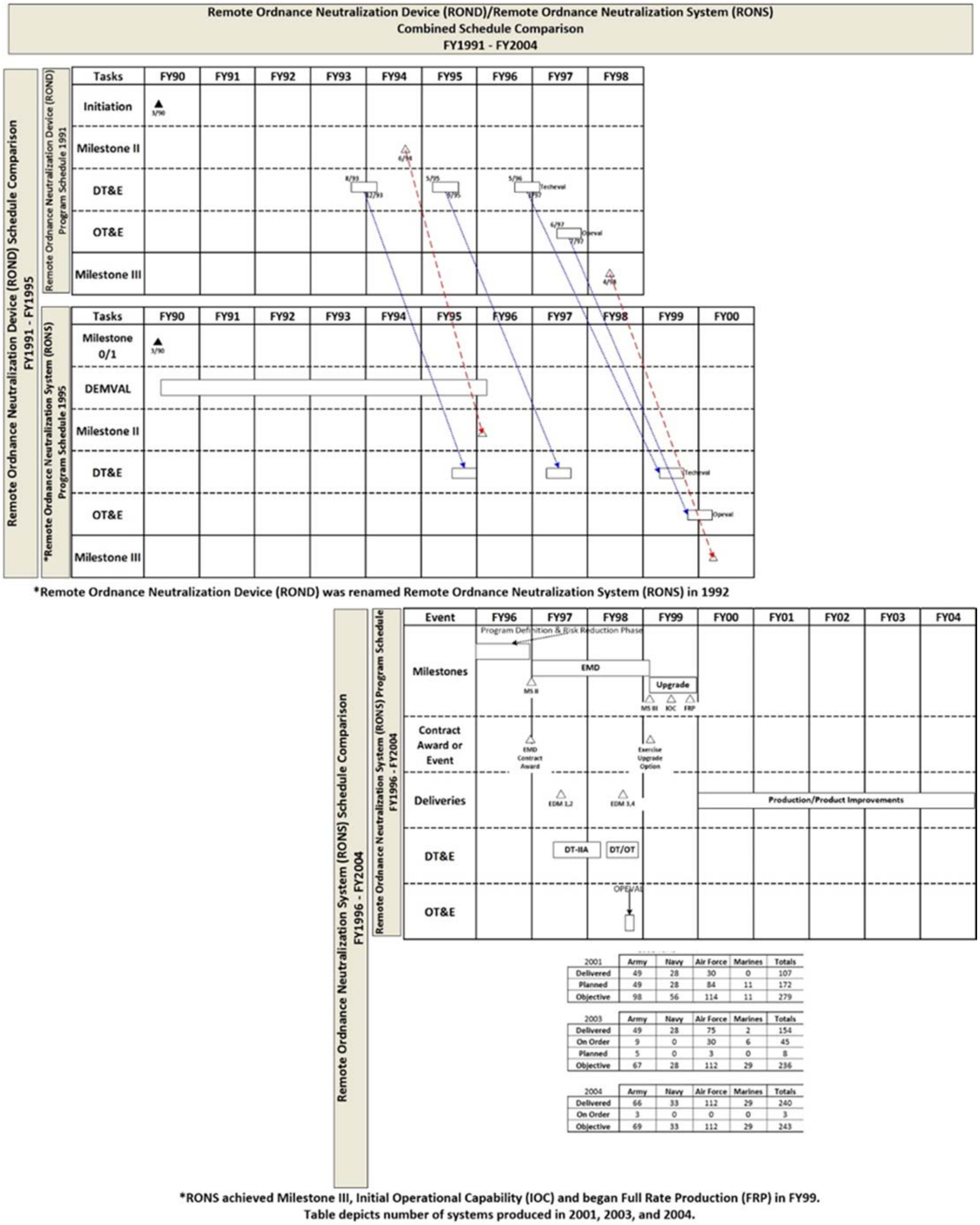
Figure 163. TUGV/TUV/FTUV/Gladiator Funding Comparison 1991–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

2. RONS from 1991 to 2004

RONS is the second of three programs that began in the 1991 master plan. From a formal acquisition standpoint, this is probably the most successful UGV program in the portfolio. Figure 164 compares RONS' schedules from 1991 to 2004. The first program schedule in 1991 planned for Milestone III/C achievement in FY98. In the 1995 master plan, the schedule displayed a schedule slip and a planned Milestone III/C decision in FY00. Further research verified that the program actually achieved Milestone III/C in FY99. Ultimately, the program schedule recovered and over the span of eight years, only slipped one year off from the original master plan.

The schedule not only recovered, but the program delivered 243 systems to users in the field. This was the first UGV program to achieve full rate production, which is a significant amount of UGVs delivered for this period of time. Funding for the program was sufficient in the first few years of the program, but then experienced a significant budget cut for four years from FY95 to FY98, as depicted in Figure 165. This may be why the program schedule began to shift further into the future. The funding increased significantly in FY99, the year that production began, and fluctuated based upon the amount of systems acquired in each year.

It is important to note that the RONS program is a niche program that supports EOD. The demand from users for this program is quite apparent and appears to pull the program to success even when funding was cut significantly; the program managed to fight its way into the hands of users.



2001	Army	Navy	Air Force	Marines	Totals
Delivered	49	28	30	0	107
Planned	49	28	84	11	172
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2003	Army	Navy	Air Force	Marines	Totals
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On Order	9	0	30	6	45
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2004	Army	Navy	Air Force	Marines	Totals
Delivered	66	33	112	29	240
On Order	3	0	0	0	3
Objective	69	33	112	29	243

Figure 164. ROND/RONS Schedule Comparison Illustrates Milestone Slippage 1991–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

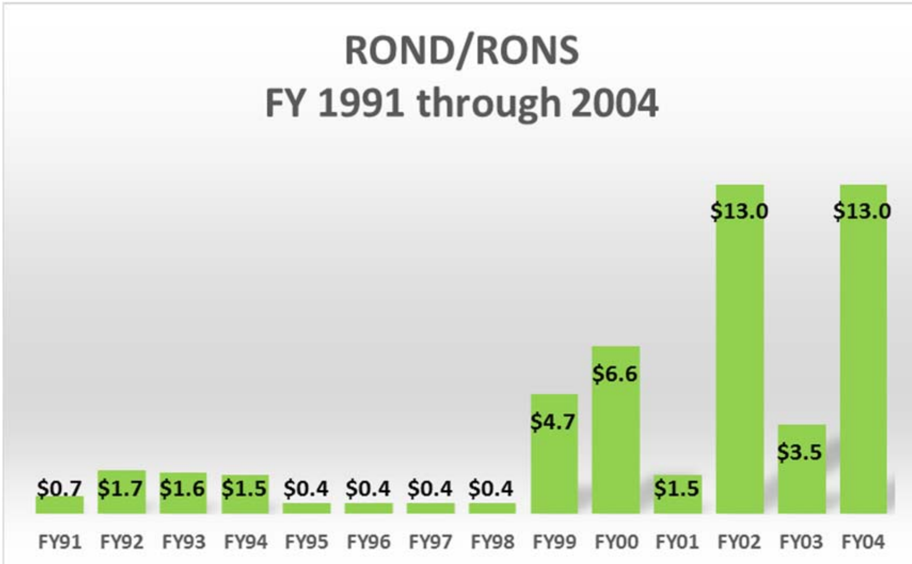


Figure 165. ROND/RONS Funding Comparison 1991–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

3. RACS from 1991 to 2004

RACS is the last of the three original programs from the 1991 master plan. The original program name was RRR. This was the second program in the portfolio to achieve Milestone III/C, which occurred in 2001. In Figure 166, the program experienced schedule challenges and did not achieve the original planned production date of FY97 from the 1991 master plan. The original system, an excavator, was not the system that became the fielded product. The ARTS system, a much smaller vehicle with a standard plow and a variety of attachment tools to accomplish various missions, was the system that eventually made it to the warfighter.

Like the RONS program, this program serves a niche community: the EOD and Engineer range clearance community. This system is used to clear war zones or old target ranges of UXO. It allows the operator to deploy a robot to conduct digging, moving, and neutralization of munitions from a safe distance. After the collapse of the Soviet Union, the need arose to clear large training areas and the DOD and contractors became interested in this piece of equipment. These are pull factors, which allowed the program to survive and prevail. The change in the demand situation salvaged this UGV program and system to meet the needs of users in a different capacity. The platforms evolve based on user demand relative to the current threat. Currently, four systems reside in the RACS program; three are based upon the need to clear ranges and the latest program, known as REDCAR, is designed to provide security of bases and other facilities with the ability to lethally engage adversaries with organic weapon systems. Again, the demand pulls technology from an existing platform to meet this requirement. From a warfighter function standpoint, all capabilities in the RACS program fall under Force Protection, generally serving a defensive function.

From 1991 to 2001, the program received modest funding that fluctuated year after year. From 2002 to 2004, the funding for this program, as depicted in Figure 167, increased significantly; this increase can likely be attributed to the achievement of full rate production. The money required to acquire the system is significantly higher than the R&D costs. Additionally, the program grew in terms of number of systems, and generally, with more systems comes more funding.

At this point in time, the technology is limited to remote control by an operator or semi-autonomous deployment by an operator. The system can receive very structured map data, which commands the system to search and clear within the boundaries of a specified area. The machine is capable of picking up discovered UXO and moving it to a designated area where reduction operations are initiated.

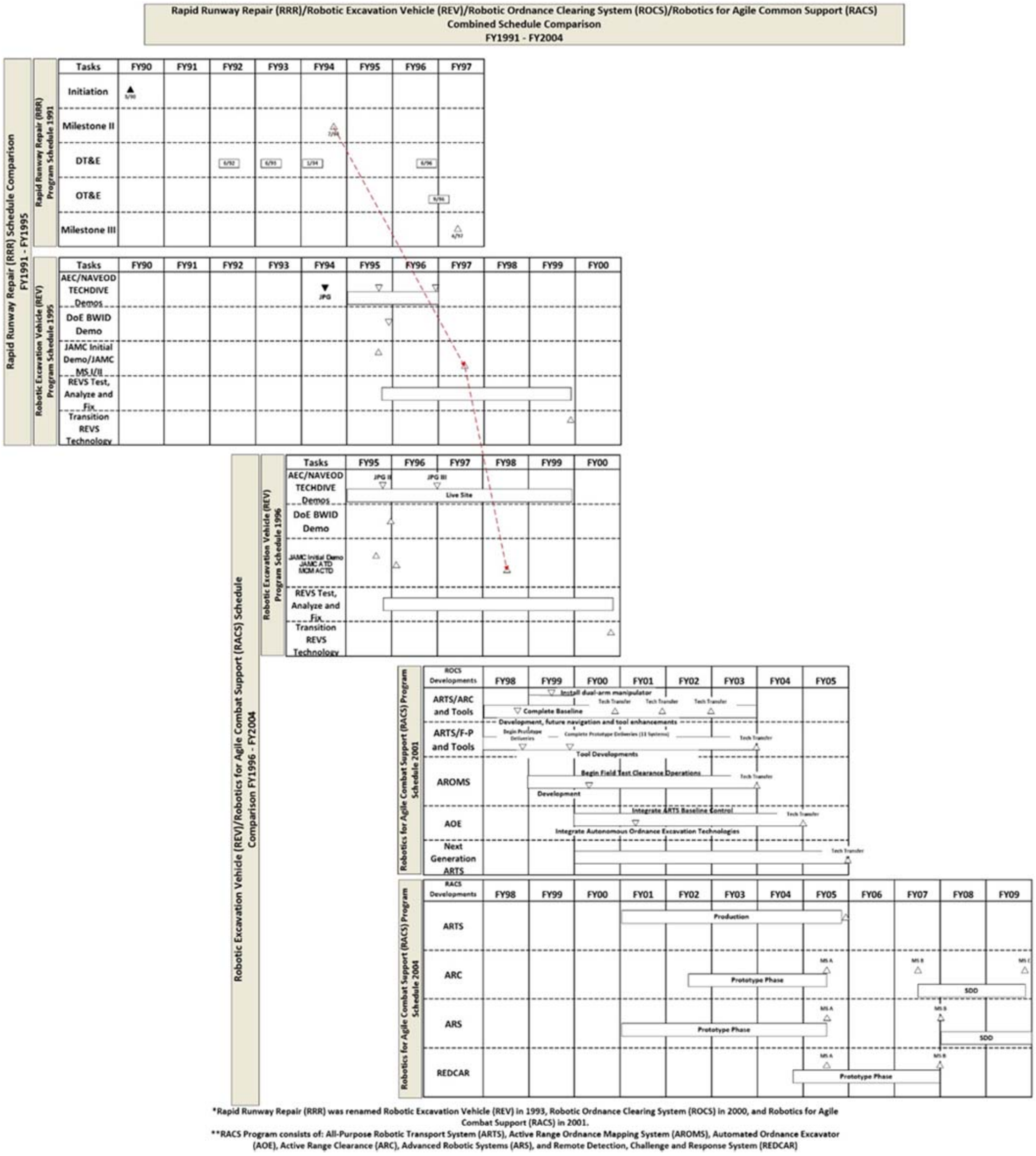


Figure 166. RRR/REV/ROCS/RACS Schedule Comparison Illustrates Milestone Slippage 1991–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

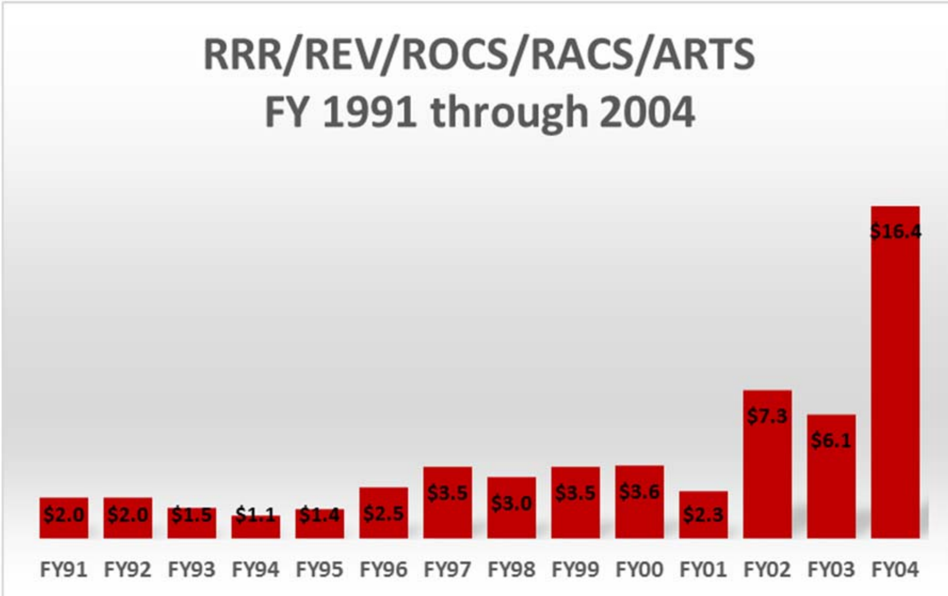


Figure 167. RRR/REV/ROCS/RACS Funding Comparison 1991–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

4. CRS from 1994 to 2004

The CRS program, which began as the EVTC program in 1994 has an interesting history and serves as a great example of unexpected demand resulting from changing requirements. From 1994 to 1995, the program experienced an immediate schedule slip and appeared that further schedule slippage would occur again in the future. However, the United States became engaged in the Bosnian conflict in 1995, and immediately this program became the highest priority among UGV programs. It became a high priority primarily due to the pull factors from the warfighters in Bosnia. The warfighters demanded a solution to clear safe lanes through the minefields for the passage of mounted convoys and dismounted patrols.

As the demand for the capability arose, the schedule for this program in Figure 168 accelerated as EVTC systems arrived and were installed on Engineer vehicles in Bosnia. Program funding in Figure 169 more than doubled from 1996 to 1998, and the systems proved their value on the battlefield. Hundreds of mines were cleared with the use of the EVTC kits on vehicles typically driven by human operators. The operators were able to sit at a safe distance, in another vehicle, and remotely clear safe lanes for the passage of troops.

Around the year 2000, the schedule for this program began to experience significant delays. Milestone III/C shifted from FY98 in the 1996 master plan to FY01 in the 2000 master plan and finally out to FY06 in the 2004 master plan. There is no clear explanation for what happened to the program and why the schedule slipped so far into the future. Simultaneously, the funding became erratic from FY99 to FY04, experiencing almost 300% funding swings between years.

It is evident that pull factors brought success to the program during the years the system supported warfighters in Bosnia. It also appears that the program began to push the technology beyond its demand limits and was simply not desired by the user community in the quantity forecasted by the program office. The program experienced its success in a niche community among Engineers conducting route clearance. Beyond this community, the demand for this system is practically non-existent.

The most surprising observation about this program is that demand for this capability was not high during the conflicts in Afghanistan and Iraq. There is limited discussion about the deployment of this capability among the forces deployed in support of OEF and OIF. It would be interesting to know if warfighters outside of the EOD and Engineer communities knew that such a capability existed. It appears this system would have been an ideal piece of equipment to utilize for route clearance during the conflict in Iraq.

This may be an example of a competency trap or a breakdown in communication between different military communities. In Afghanistan and Iraq, the warfighter encountered IEDs and began to develop techniques to detect and survive against the threat. The warfighter became good at this procedure using inadequate technology while unmanned systems that were used in the Balkans sat in warehouses. Another consideration is that personnel who deployed to the Balkans did not communicate about this capability as the IED threat emerged in Afghanistan and Iraq. Young service members on the ground were simply unaware of such a technology and there was no push factor to generate the demand for this capability.

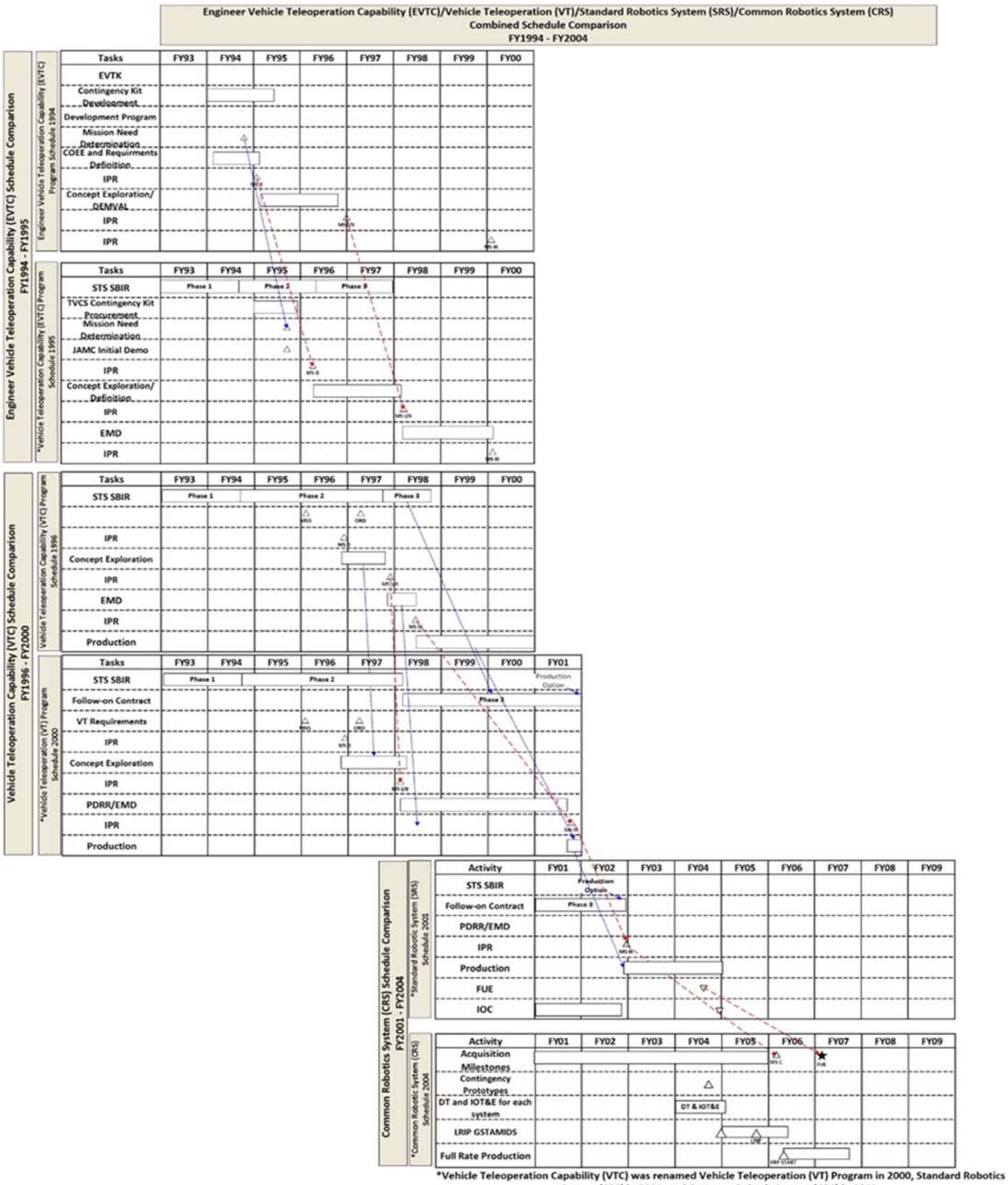


Figure 168. EVTC/VTC/VT/SRS/CRS Schedule Comparison Illustrates Milestone Slippage 1994–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

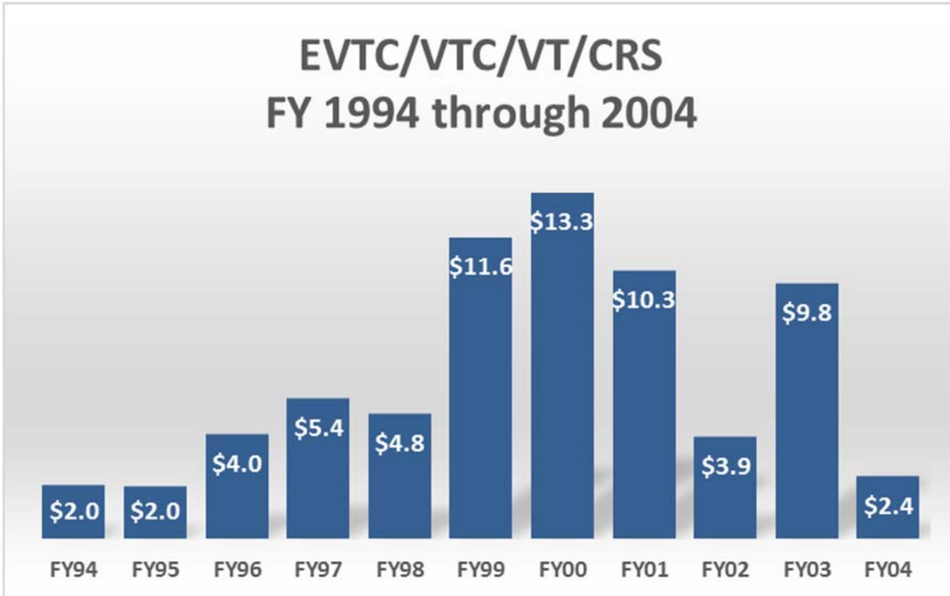


Figure 169. EVTC/VTC/VT/SRS/CRS Funding Comparison 1994–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

5. MDARS-E/I from 1994 to 2004

The first MDARS program schedules surfaced in the 1994 master plan, as depicted in Figure 170. This program is interesting because it is managed outside the joint robotics program and controlled by the Physical Security Equipment Management Office (PSEMO). This program appeared to be the "outsider" program in some regards. The program is a highly complex program designed to conduct security inside and outside the perimeter of large warehouses. This system conducts its patrols autonomously with one operator overseeing up to 30 systems simultaneously. The autonomous capability is possible with this system because the boundaries that the machine operates within are highly structured.

It the period analyzed, the system never achieved Milestone III/C or full rate production. In fact, the schedule generally slipped further into the future with each new master plan. The first Milestone III planned in the 1994 master plan was to occur in FY98. By 2000, this milestone shifted out to FY02, and in the latest master plan, Milestone III/C is planned for FY06, for both the Exterior and Interior variants.

Essentially, Milestone III/C shifted about eight years further into the future than originally planned.

The slippage in schedule does not necessarily mean the program is a failure but the technology to make this program successful is very complex; it takes a lot of time and money to mature such a technology. At one point in time, it appeared that civilian companies had an interest in this technology. A demand for the technology suddenly appeared and the pooling of R&D from DOD, academia, and industry should have propelled this system into development. However, the demand may not have been large enough to keep the program on schedule, or the technology simply proved too challenging during the time period.

While the MDARS program did not achieve full rate production during the time period covered, it certainly shared technology with other programs in the portfolio. The overall UGV community is arguably better off because of the MDARS program. This program demonstrated capabilities that will lead to its future success, as the technology matures further.

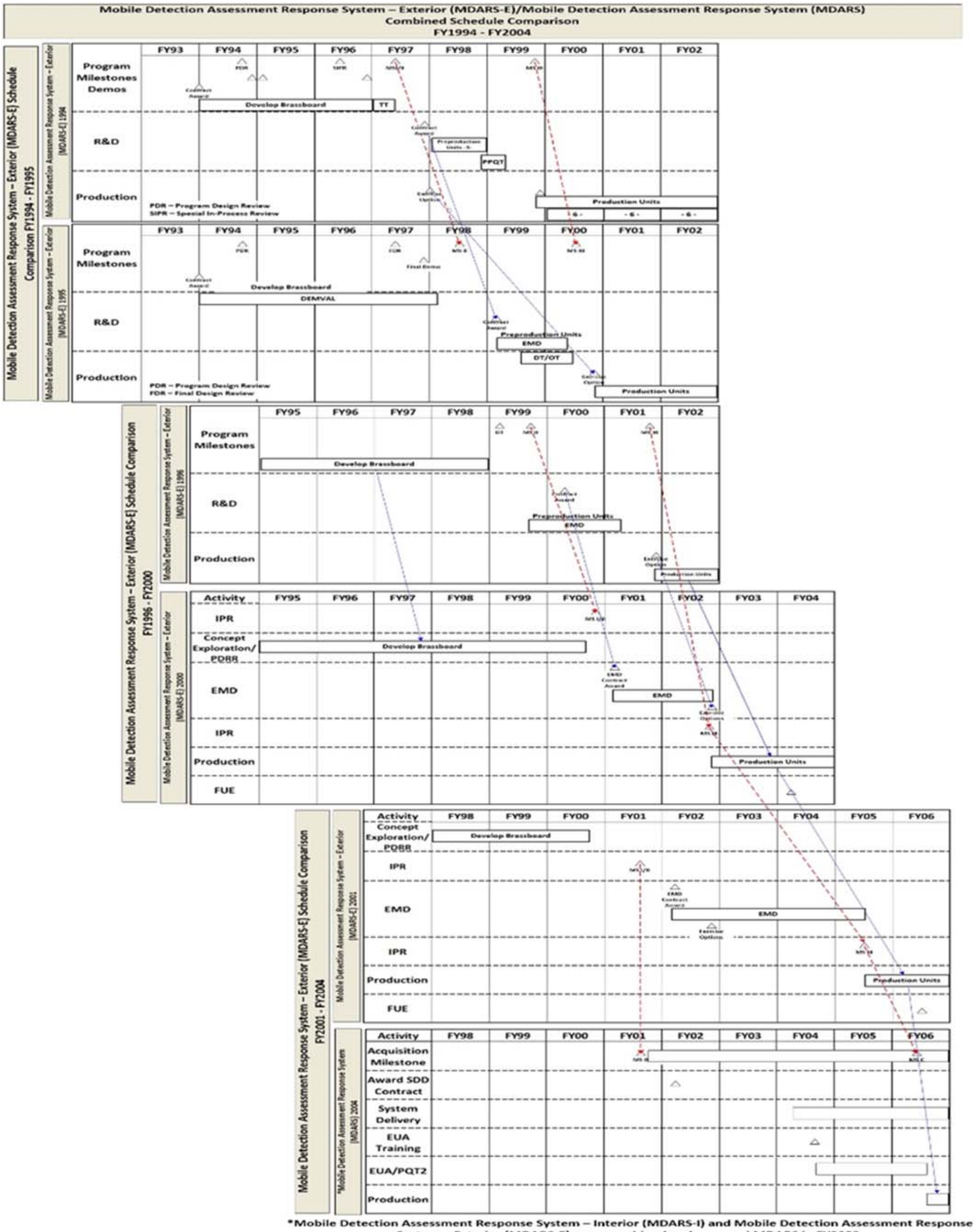


Figure 170. MDARS-E/I Schedule Comparison Illustrates Milestone Slippage 1994–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

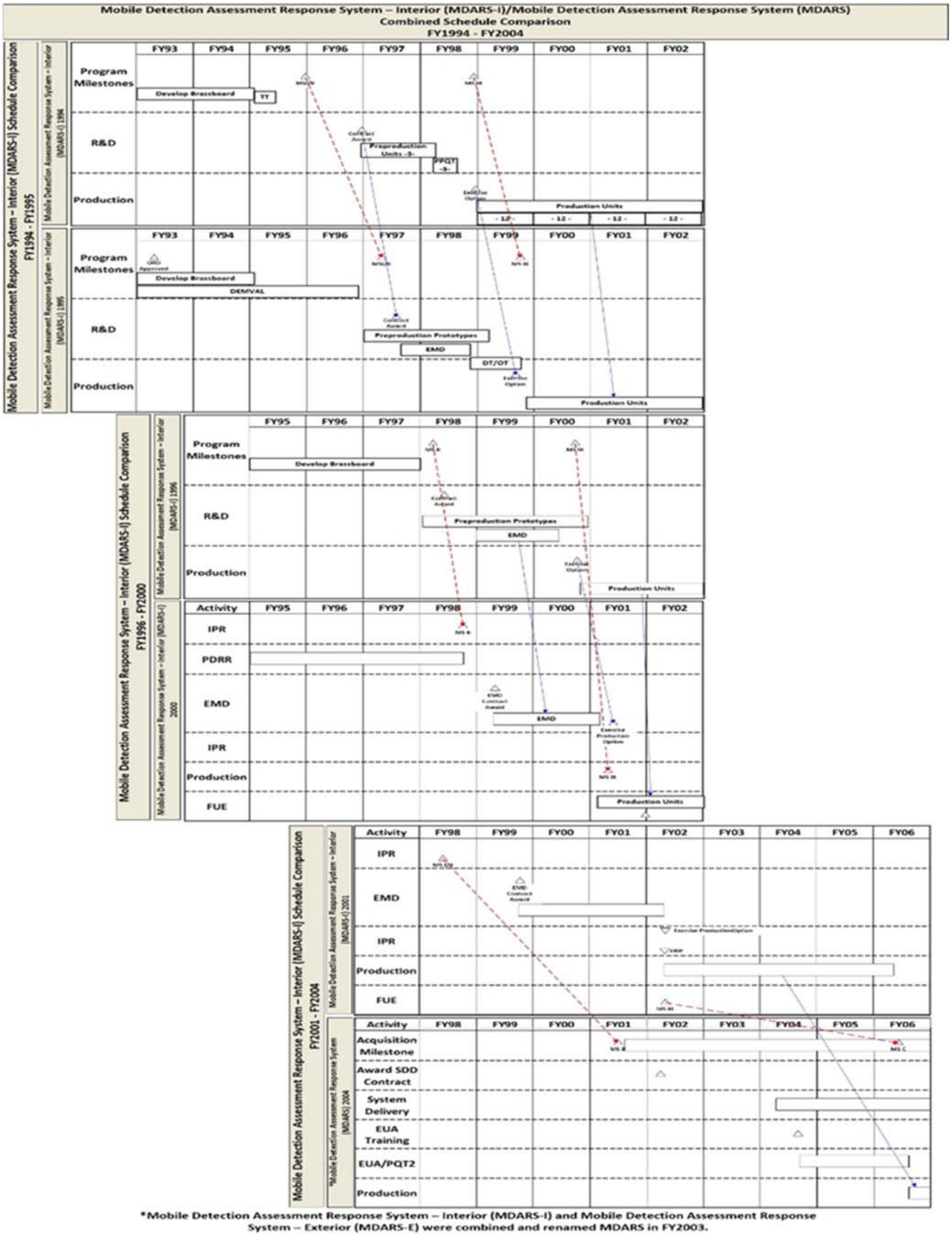


Figure 170 cont'd. MDARS-E/I Schedule Comparison Illustrates Milestone Slippage 1994–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2001, 2003, 2004)

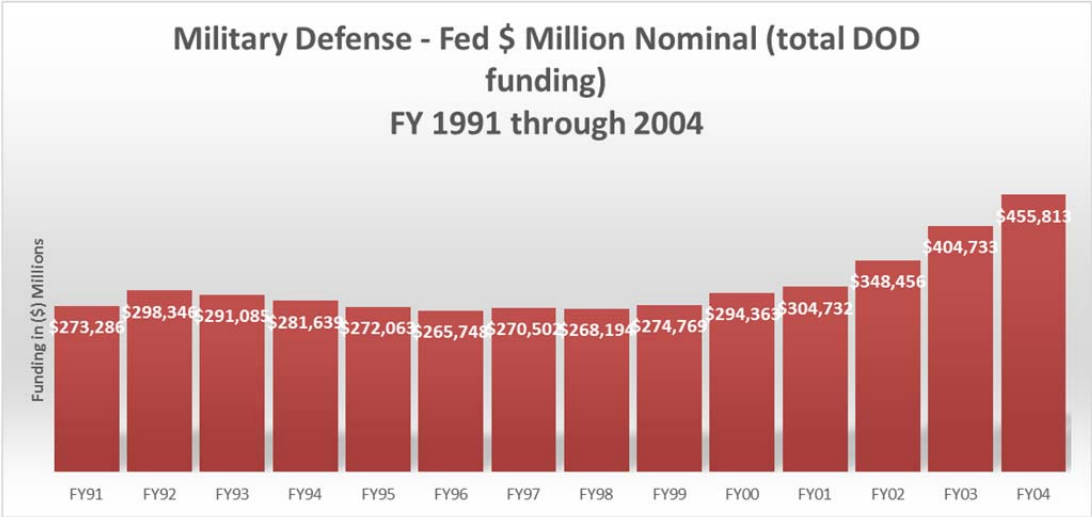
6. DOD Funding Compared to UGV Funding from 1991 to 2004

As previously stated, the researchers assumed that the DOD budget and the UGV budgets would be more correlated, meaning that the UGV budget would rise and fall with the DOD budget. In fact, in Table 57 the correlation is almost zero when the full time period is examined. In many years, the DOD budget rose and the UGV budget declined, as depicted in Figure 171. This gives the impression that UGVs were not high on the overall DOD budgetary priority list. Unmanned systems appear to be valued and more money is likely to flow into future unmanned programs, but there are other programs that have a higher value and priority in the eyes of the DOD. Perhaps Congress expected UGV technology to develop at a faster rate and this possibly hurt funding in later years. A quick glance at the first four years of UGV funding gives the impression that people were overly optimistic about the outcomes.

Table 57. DOD and UGV Funding Correlation (after DOD 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004; usgovernmentspending.com, n.d.)

Programs (6.3B Advanced System Development - ASD)	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	Total
DOD Unmanned Ground Systems Funding: Millions	$41.6	$41.8	$62.4	$79.3	$23.1	$21.2	$27.9	$26.8	$31.1	$30.3	$28.6	$27.6	$46.5	$37.2	$525.4
Military Defense - Fed $ Million Nominal (total DOD funding): Billions	$273.2	$298.3	$291.0	$281.6	$272.0	$265.7	$270.5	$268.1	$274.7	$294.3	$304.7	$348.4	$404.7	$455.8	$4,303.7

Correlation from 1991 to 2004	0.0794



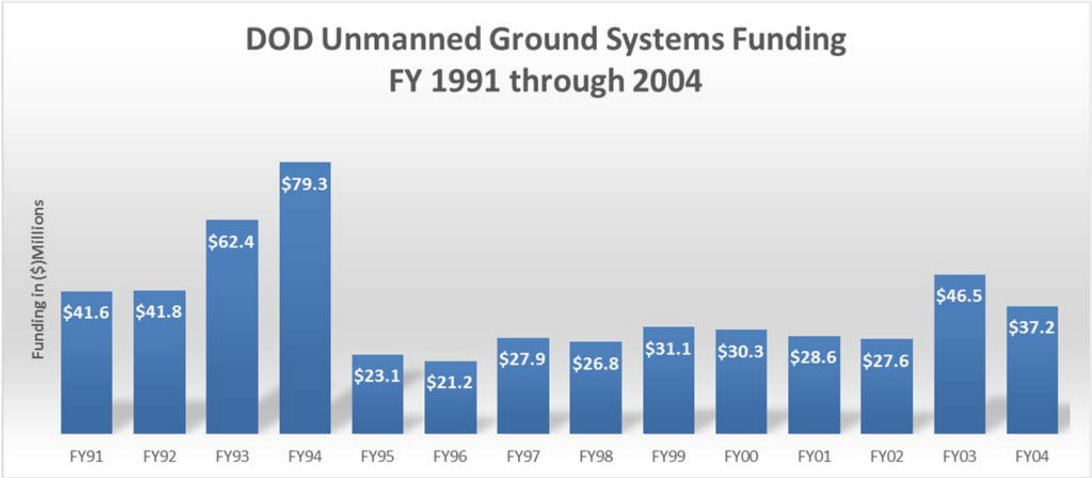


Figure 171. DOD and UGV Funding Comparison 1991–2004 (after DOD 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004; usgovernmentspending.com, n.d.)

7. The Man Transportable Robotic System (MTRS) Example: 2003 to 2007

The years of this program extend beyond the scope of this research, but it is such an interesting case that it is worth covering in this research project. The MTRS program includes the TALON and PackBot robots, which serve a niche purpose within the EOD community. The systems are first mentioned in the 2003 master plan where it is learned that the EOD community began demanding its capabilities in FY01. This scenario shows the power of pull factors that users have on the acquisition process when something is deemed highly valuable and highly demanded.

As depicted in Figure 172, in FY01, an Analysis of Alternatives was conducted and the EOD community determined that a commercial-off-the-shelf (COTS) approach would best serve their needs. In May 2002, solicitations were sent to vendors, and in June/July of the same year, proposals were reviewed and evaluated. In October 2002, iRobot (PackBot) and Foster-Miller (TALON) were awarded contracts. By February 2003, seven PackBot and TALON systems were delivered. The DOD planned a production decision for the second quarter of FY05 and production of the systems by both companies was approved. In 2003, the DOD set an objective of 250 total systems, and by 2005 the new objective increased to 1056 systems. By 2007, 836 systems arrived to warfighters with another 536 planned for a total objective of 1372 systems. This is more systems fielded than all other programs combined from 1991 to 2004 (DOD, 2003, 2004, 2005).

In a matter of six years, the PackBot and TALON went from an idea in the mind of an EOD technician to a fully fielded and functional system in the hands of users on the battlefield. This example proves that the DOD can deliver quality systems that users demand in a short period of time. A COTS solution can be delivered into the hands of the customer using an abbreviated acquisition procurement time line and not having to go through the lengthy joint capabilities integration development system (JCIDS) process. This program is possibly the best example of the power of pull factors on a new technology. The EOD technicians desired a robot that provided standoff from IEDs and allowed them to manipulate objects with a strong, yet precise arm. The warfighters also demanded a system that was rapidly deployable, light, easy to use, and easy to replace. This program can certainly serve as an example for future acquisitions, and perhaps it best demonstrates it is better to develop systems based on the need or pull as opposed to pushing systems that users may not truly desire. This system also benefits the UGV community because of the large quantity of units fielded. The systems received a lot of exposure and integration among troops. Surely many warfighters saw the PackBot and TALON in action on the battlefield and began to gain comfort in conducting combat operations in conjunction with UGVs.

Further research showed that iRobot worked on projects with DARPA during the mid- and late-’90s. In 1998, iRobot was awarded a contract by DARPA for the development of a tactical mobile robot; this led to the development of the PackBot (iRobot, 2014). This is essentially how the iRobot Corporation gained entry into the DOD. More details emerged that helped better explain the immense demand of these systems at the onset of Afghanistan and Iraq. Tim Trainer, the Vice President of iRobot product management, said,

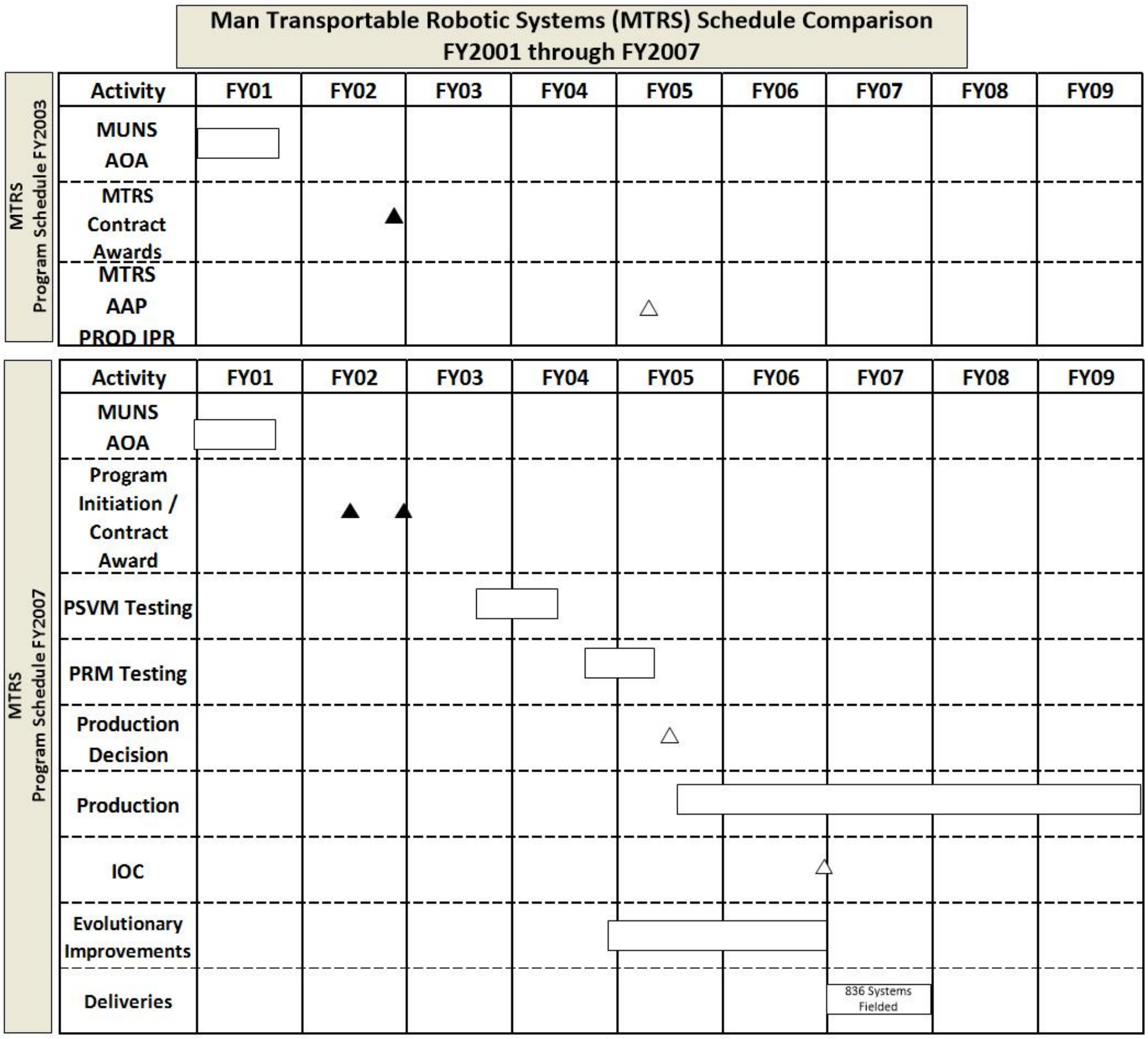
> In the early 2000s, we had a contract with DARPA and thought it might be better to send a robot instead of a Soldier into Afghani caves to see if they held weapons caches . . . Soldiers [carried our robots] 15,000 feet up Tora Bora, used them in the caves, and gave us an understanding on what we could do better. That was our first production contract, if you will. (Love, 2014, para. 4)

Information on the Foster-Miller Talon robot was not as available as information was on the iRobot. This robot also has a history with the military that predates the information presented in the 2003 master plan.

> The Talon began helping with military operations in Bosnia in 2000, deployed to Afghanistan in early 2002 and has been in Iraq since the war started, assisting with improvised explosive device detection and removal. Talon robots had been used in about 20,000 missions in Iraq and Afghanistan by the end of 2004. (GlobalSecurity.org, n.d., para. 5)

When this statement is compared to the 2003 master plan, it is evident that the Talon was in field use before production for the DOD was even planned on the master plan schedule.

The information uncovered shows that it was not so much serendipity that led to the success of the PackBot and Talon, but early exposure to users and the backing of a legitimate agency like DARPA. The two systems are small and have some of the best capabilities of their time and obviously were in demand by the warfighter. This explains why the Analysis of Alternatives that was conducted in 2001 by EOD technicians led to the request for a COTS solution from these two systems. The warfighters previously used and were somewhat familiar with the products, leading to a high demand for the product as OEF and OIF became larger conflicts.



MTRS	FY03	FY04	FY05	FY06	FY07
Delivered					836
On Order					
Planned		806	1056		536
Objective	250	806	1056		1372

Figure 172. MTRS Schedule Comparison 2003–2007 (after DOD, 2003, 2004, 2005, 2007)

E. THE DARPA INTERVENTION

This research covers UGV master plans from 1991 to 2004, and while there are some fielded systems to warfighters, the technology of the fielded systems did not advance significantly in the 14-year period, proving the complexity of the problem. There are some significant technology developments for UGVs in the period examined, but the technology is not in the hands of users and not fully integrated among the force. The remote ordnance neutralization system (RONS), all-purpose robotic transport system (ARTS) from the RACS program and engineer vehicle teleoperation capability (EVTC) systems are the only fielded UGV systems from 1991 to 2004. These are all basically remote-controlled (RC) systems. In some cases, there is the capability to deploy the robot to a location, and the robot can then conduct path retrace and come back to its original deployment location. From a big picture point of view, this is not a major technological breakthrough. Very determined and intelligent people from DARPA, Carnegie Mellon, and the DOD defense industry dedicated themselves and committed significant funding to UGVs in the period covered. Many gains were made, but none that led to a fielded robot beyond the Teleoperation capability. This further supports the claim that a major technological breakthrough must occur in order for UGVs to achieve a higher level capability such as fully autonomous operations.

The DOD stopped making master plans in the year 2004, which is also the same year that DARPA announced its first Grand Challenge. The cessation of plans gives the perception that the DOD reached out to DARPA and asked them to boost the stagnant UGV program. The contractors working on the current programs of record (POR) could not deliver the innovative breakthroughs that the DOD desired so it was time for DARPA to reach out to a broader community. “The Grand Challenge was designed to reach beyond the traditional base and tap into the ingenuity of the wider research community” (DARPA, 2014, para. 2).

In 2004, DARPA held the first Grand Challenge in which competitors were offered a winner-takes-all prize of $1 million. The prize would go to the first unmanned vehicle to travel 142 miles autonomously across the desert and cross the finish line in less than 10 hours. Fifteen vehicles qualified for the race; half of them died within the first half mile of the starting line and none of the vehicles completed the race. The vehicle that made it the farthest distance traveled only seven miles.

In 2005, shortly after the first race, DARPA announced it would conduct a repeat of the Grand Challenge. The prize was raised to $2 million, winner takes all for the first autonomous vehicle to travel 132 miles across the desert and cross the finish line. Forty-three teams competed for the 20 available slots in the race and a total of five teams finished the race. A vehicle named Stanley from Stanford University finished in first place with a time of six hours and 20 minutes. The overall R&D funding spent by the competitors is unknown at this time. It is important to understand the dollar amount spent by the 40 or so teams that led to the major achievement of this event. This information is relevant because it may prove that it does not necessarily require a large sum of money to achieve a major technological breakthrough.

This event proved the power of a prize competition to promote innovation. In a span of two years the world saw no vehicles capable of autonomously traveling farther than seven miles to five vehicles autonomously completing a 132-mile off-road course. Almost all competing vehicles made it farther than seven miles in the second Grand Challenge. This also shows the challenge facing the DOD in the development of UGVs that warfighters want and demand. LTC Scott Wadle, USMC, said,

> The first competition created a community of innovators, engineers, students, programmers, off-road racers, back yard mechanics, inventors, and dreamers who came together to make history by trying to solve a tough technical problem. The fresh thinking they brought was the spark that has triggered major advances in the development of autonomous robotic ground vehicle technology in the years since. (DARPA, para. 4, 2014)

The DARPA Grand Challenge is an excellent venue to make believers out of non-believers. There are bright minds around the world that will come up with far-out, never-imagined ways of solving complex problems. There are also different ways to solve a problem so the UGV community benefits from seeing multiple options that can be further explored to achieve technological breakthroughs. More variety leads to more potential solutions, which lead to more winning solutions in the long run.

There is great value in follow-on research of the UGV community from 2004 to present day to see the impact that the Grand Challenge and DARPA had on technology development. The Grand Challenge raised the bar and proved that far-out ideas are achievable. It will be valuable to see the role that DARPA plays in the future years of UGVs. While the Grand Challenge was a great accomplishment, there are still many other missions and capabilities within the UGV community that must be overcome to achieve full autonomy and for the military to realize the full potential of these systems.

F. SUMMARY OF ANALYSIS

From the extensive research conducted on the UGV master plans from 1991 to 2004, there are four key points which best summarize the findings.

1. A balance of push and pull factors that can successfully integrate new technologies must be present.
2. Technologies are very complex, and even with significant R&D funding and top personnel and organizations working on the problem, a solution may not be found.
3. Communication breakdown between military services and various communities within the DOD may result in technology stagnation from one conflict to the next due to lack of visibility.
4. The portfolio of UGVs from 1991 to 2004 generally serves the Force Protection warfighter function.

Figure 173 best describes the first key point from this research. Along the bottom axis, UGV programs are aligned with conflicts involving the United States, which likely drove the development of specific UGV systems. Along the left axis is the percentage of overall UGV funding that a specific system consumed during the three conflict eras. In the column for each system, a majority rating of push or pull was given to each system for each conflict era. While the requirement or demand for each program existed to some extent, push and pull ratings were determined based on delivery of systems to the warfighter.

Generally speaking, at the beginning of the UGV program, all systems were primarily pushed to the warfighter. All of the programs listed in Figure 173 used 6.3B advanced system development R&D funding. Basically, these were concepts that were created for demonstration purposes, with the objective of generating user demand and evolutionary development. Over the years, the prototypes became effective and suitable solutions for specific threats relevant to the conflict era. This led to demand or pull factors from the user operating within the conflict regions.

As the program matured, the push to pull ratio became more balanced. A larger portion of UGV funding was appropriated to programs experiencing higher user demand. Further research and analysis may reveal that systems that generated user pull also may be lagging indicators. For instance, the CRS program experienced high user demand in the Balkans from 1995 to 2000, but the demand for the system dropped significantly as conflicts began in Afghanistan and Iraq. The funding still remained high for this program even though there were no full rate production fieldings for future years. Another consideration for this particular program is explained in greater detail in point number three of the key take a ways. From 1991 to 2004, 57% of all UGV funding was dedicated to push and 43% of all funding went to UGVs that were pulled from the warfighter.

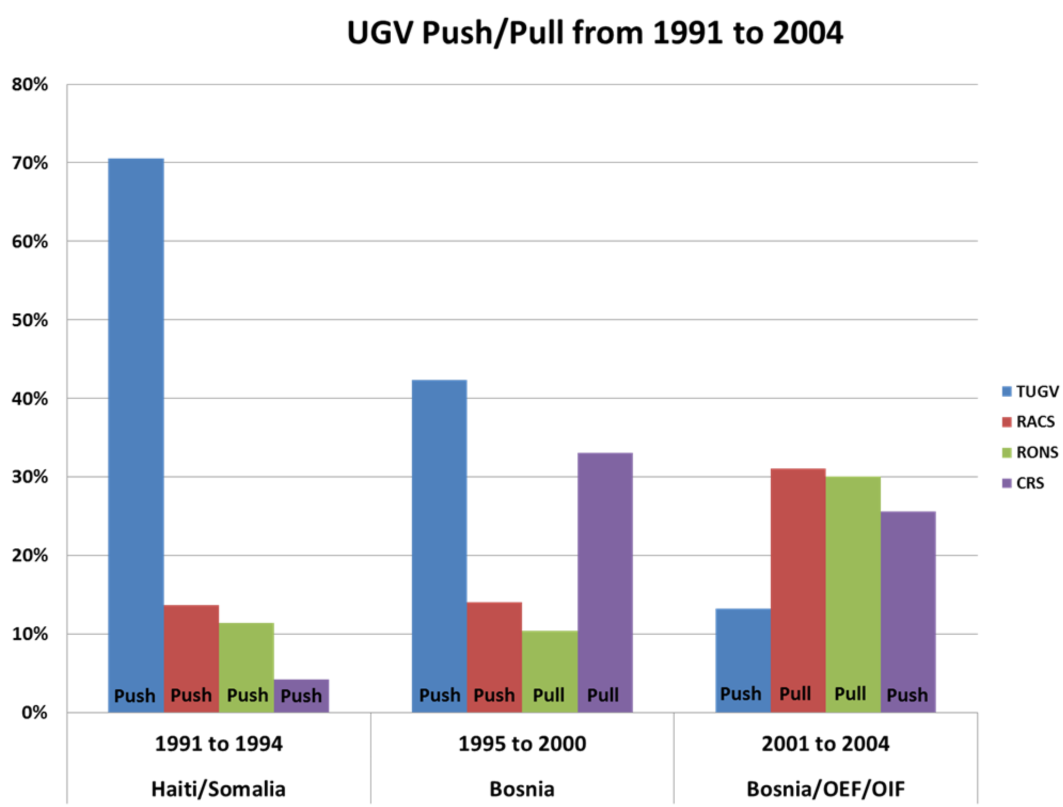


Figure 173. UGV Push/Pull from 1991–2004 (after DOD, 1991, 1992, 1993, 1994, 1995, 1996, 2000, 2001, 2003, 2004)

Key take away number two acknowledges the challenge of developing UGV technology. This technology requires the development and integration of highly complex sensors and software to function properly. There have been significant gains in both areas in the 14-year period measured, but UGVs have yet to achieve their full potential. Achieving full autonomy in an unstructured environment has proven difficult to accomplish and agencies such as DARPA, the defense industry base and academia are working diligently to bring this to fruition.

Key take away number three speaks to the case of the EVTC/VTC/VT/CRS program. This program experienced significant pull factors from warfighters as the U.S. role in Bosnia increased. Warfighters operated remotely controlled vehicles from a safe location and conducted minefield clearing operations for mounted and dismounted troops. There are several reports of this program's success in the master plan, with hundreds of mines neutralized because of this capability. From 2001 to 2004, the United States became engaged in combat operations in Afghanistan and Iraq and warfighters faced threats similar or more dangerous to the threats they faced in Bosnia, yet the CRS program did not experience the same pull factors.

It is likely that the warfighter did not demand this UGV capability in Afghanistan and Iraq, but there may be other lessons learned from this case. Why would U.S. warfighters not want this capability, particularly in Iraq? Further research may better explain this question, but the initial answer is that a communication breakdown occurred between services and communities or there was a competency trap.

It is also possible that warfighters in Iraq were not aware that remotely operated UGVs existed. The majority of the warfighters on the ground in Iraq did not serve in the Balkans and would not know of the mine clearing vehicles without being informed about them. Perhaps this capability was not communicated to the warfighter. Another notion is that the warfighter in Iraq fell into a competency trap. The warfighters had to quickly react to the IED threat in Iraq with the equipment they had available at the time and they became extremely proficient at defeating IEDs with inferior equipment. Warfighters added armor to vehicles, traveled at varying speeds and developed techniques to increase survivability. Eventually, vehicles were produced with additional armor and became larger in size. However, a more sophisticated piece of equipment was available, but unused. The warfighter was clearing routes in Iraq manually in Engineer vehicles, but this could have been accomplished with the CRS system that was employed in Bosnia. It is difficult to measure the level of push of this program in Iraq making it a worthwhile topic to further research.

Key take away number four is best supported by Table 58. The table is based off of data analyzed in the research and on an unmanned ground vehicle study conducted by the Department of the Navy (DON) in 2001. The table is centered on the six warfighting functions of maneuver, fires, sustainment, intelligence, force protection, and command and control. Under each warfighting functions are the Notions of Employment (NOE) for UGVs. This essentially means that analysis revealed past or potential use of UGVs for the following sub-missions under each warfighting function. Along the upper left axis of the table are the years examined and the conflicts ongoing in the period covered.

Any UGV system or program covered in this research is placed under the appropriate warfighting function for that system or program. The corresponding number indicates the NOE for that system or program. Some systems and programs do have utilization under multiple warfighting functions and NOEs but categorization is based on primary intended use as indicated in the master plans.

The majority of all programs and systems fall under the force protection warfighting function; 14 systems and programs in total over the period measured. This is not necessarily a negative point and this may validate the strong pull factors that come from niche communities, particularly EOD and Engineer users. On the other hand, it is worth considering that the portfolio of UGVs is too heavy on force protection. UGV programs seem to naturally gravitate to use under this warfighting function. Consider the UGV programs and systems that are listed under other warfighting functions: the TUGV, MULE and MPRS programs did not achieve full rate production. The TUGV and MULE programs appear to exhibit limited pull factors from the warfighter in the years examined.

UGV technology may not fully integrate into the DOD until there is more of a balance of systems across the warfighting functions. It is important to field systems that conduct other warfighting functions if UGV technology is to become a regular part of our military forces.

Table 58. Warfighting Functions and Notions of Employment (NOE) (after DON, 2001)

Year	Conflict/Threat	Unmanned Ground System (UGS)					
2004	OEF-A/Iraqi Freedom (OIF)						
2003	OEF-A/Iraqi Freedom (OIF)	MULE (12)		MULE (2)		Gladiator TUGV (1)	
2002	9/11-Afghanistan (OEF-A)						
2001	9/11-Afghanistan (OEF-A)				MPRS(2,4,5,9,11) MTRS (2,4,5,9,11)	MPRS(4,5,6) MTRS(4,5,6)	
2000	Bosnia/Kosovo Peace Keeping					BUGS (4,5) ARTS (4,5,6) AROMS (4,5,6) AOE (4,5,6) RCSS (4,5)	
1999	Bosnia/Kosovo Peace Keeping						
1998	Bosnia/Kosovo Peace Keeping						
1997	Bosnia/Kosovo Peace Keeping						
1996	Bosnia/Kosovo Peace Keeping						
1995	Bosnia/Haiti						
1994	Bosnia/Haiti						
1993	Bosnia/Somalia	EVTC(9)				REV (5,6) EVTC (5,6,8)	
1992	Bosnia/Somalia					MDARS (7)	
1991	Desert Shield/Storm	TUGV(1)			TUGV(2,3,4,5)	TUGV (1) RRR (2,3) ROND (4)	
Warfighting Functions							
		Manuever	Fires	Sustainment	Intelligence	Force Protection	Command and Control
Warfighting Notions of Employment (NOE)		1. Point for Infantry	1. Rifle Squad/Fire Team Base of Fire	1. Convoy Escort	1. Amphibious Reconnaissance	1. NBC Reconaissance	1. Communications Relay
		2. Scout for Mounted Forces	2. Robotic Flamethrower	2. Resupply	2. Route Reconnaissance	2. Teleoperated Engineer Vehicle	2. Air Defense Radar
		3. Wingman	3. Infantry Battalion Direct-Fire Support	3. Amphibious Train & Resupply	3. Deep Reconnaissance	3. Runway Repair	
		4. Amphibious MCM	4. Assault on Fortified Positions	4. Materiel Handling Equipment	4. Surveillance	4. Bomb Detection/Disposal/EOD	
		5. Obstacle Breaching in the Assault	5. Robotic Forward Observer/Target Designator	5. Artillery Resupply	5. Close Reconnaissance	5. Bomb Detection/Disposal/UXO	
		6. AP Obstacle & Minefield Breaching	6. Fire Support System	6. Firefighting	6. Robotic OP/LP	6. Range Clearance	
		7. Flank Security & Rear Guard			7. Urban RSTA	7. Automated Sentry	
		8. Obscurant Dispensing			8. Long-Term Surveillance	8. Environmental Cleanup	
		9. Exploitation/Pursuit			9. Tunnel Reconnaissance & Clearing		
		10. Remote Attack/Ambush			10. Electronic Warfare		
		11. Landing Zone Security			11. Building Reconnaissance & Surveillance		
		12. Mechanical Mule			12. Artillery-Emplace Surveillance		
		13. Assault Bridging					

V. SUMMARY, CONCLUSION, RECOMMENDATIONS FOR FUTURE RESEARCH

A. SUMMARY

Positive technological developments from 1991 to 2004 resulted in significant growth for the UGV program and community. The first master plan featured only three programs, but by 2004, the portfolio grew to 14 programs, each benefitting from shared technology, hardware, and software. The growth of the overall program is noteworthy, however, technological advancements are not ground breaking and demonstrate the complexity of UGVs. While testing of new ideas and systems is certainly ongoing, the system fielded to end-users essentially consists of a robot with a remote control. At best, the systems have the ability to operate semi-autonomously, deploying down a pre-planned route and returning automatically along the same route. However, this does not mean that the current UGVs do not have value. The UGV's purpose was to allow the warfighter to conduct mission objectives from a safe distance, primarily dealing with the detection, removal, and reduction of UXO. UGVs have undoubtedly fulfilled their purpose and have saved countless lives in combat and non-combat operations.

The overall UGV program was affected by a few trends. Members of Congress and other personnel, especially those that have the power to affect DOD program funding, should take note. Fluctuating budgets consistently limited program development and schedules in almost all master plans. Research indicates that if current funding is reduced in the next year, the schedule will probably shift and affect the desired time line and outcome of the program. If funding, however, remains consistent for these small yet innovative programs, advancement will remain more consistent and programs will reach expected goals.

From 1991 to 2004, the total funding for the UGV program is about $500 million. This is essentially a rounding error for the federal government. When this amount is distributed among all of the programs over 14 years, the dollar amount per program is quite small. However, a small change to the program's limited funding has considerable effects.

Additionally, from 1991 to 1999, almost all UGV funding went to R&D. Budget uncertainty during the R&D phase proved to be detrimental to every program schedule in the portfolio. In many cases, academia and industry rely specifically upon this funding to experiment with innovative technologies and to conduct demonstrations. It is difficult to demonstrate a technology if the funding to develop systems and prototypes is cut. While Congress would like to see immediate results from the funding, this is unrealistic, as research takes time to transform into tangible results.

Students in the acquisition curriculum must be aware that cutting-edge technology programs are at risk of schedule slippage. Another observation from the UGV program is that funding is not the only challenge to success, as complex technology itself can be a challenge. For instance, the Tactical Unmanned Ground Vehicle (TUGV) program was formally nominated as the top priority UGV program in the early years. The TUGV's primary goal is to conduct the RSTA mission, which is one of the most complex military missions. It requires a UGV to conduct highly autonomous decision-making in an unstructured environment. As of 2004, this was not possible and likely not achieved as a result of immature technology. Even when the TUGV was the most highly funded program in the portfolio, its chances of success were at a disadvantage.

The Defense Advanced Research Projects Agency (DARPA) played a role in UGV technology since the program's inception. It is not surprising that the agency was called upon in 2004 to help propel UGVs to a higher level of performance. With the desire to achieve full autonomy in unstructured environments and the lack of technological breakthroughs in this community, DARPA must continue to reach out to the world's innovators to achieve a higher level of performance. DARPA must continue to conduct events similar to DEMO I, II, III, and the Grand Challenge that raise the bar and deliver immediate tangible results.

The future of UGVs is positive, but the time line to achieve the military's desired results is uncertain. More stability in program funding will help maintain schedules and deliver results in a more timely manner.

B. CONCLUSION

There is a fine balance between push and pull factors, especially when dealing with new, cutting-edge technology. Does the warfighter actually know what new technology he or she wants if no new technological options have been presented? The answer is that warfighters need to see new options before a solution is adopted. It is necessary to explore new technologies and introduce them to warfighters for the sake of determining future needs. The warfighter must also have the ability to utilize new systems so that feedback can be provided that results in products that meet the user's needs. The warfighter will demand what is needed at the appropriate time and from this will determine which programs will become the priority for a specific period of time.

UGV technology development is extremely complex in nature. Many people and agencies have committed their lives and their money to the development of these systems. In the period of time examined, full autonomy could not be achieved, partly because current technology is not mature enough.

To maximize the available technology and to achieve a major technological breakthrough, consider the following recommendations:

1. Conduct more competitive technology development prize challenges similar to the DARPA Grand Challenge.
2. Continue to fund the development of new technology to push to warfighters.
3. Listen to the demands of the warfighter and produce a sufficient amount of the systems demanded.
4. Take feedback from the user to improve future system increments.
5. Continue to grow the UGV technology exploration community (industry, academia, and other government agencies).
6. Ensure that users are aware of all UGV systems and capabilities in the portfolio, particularly the systems that may be in warehouse storage.
7. Create a balanced portfolio of UGV systems that serve multiple warfighting functions.

C. RECOMMENDATION FOR FUTURE RESEARCH

Future research possibilities are endless and potentially impactful. During this research project, four key areas for future focus surfaced.

1. Complete the historical analysis of the UGV program from 2005 to present. Consider the use of the DOD unmanned systems integrated roadmaps or utilized individual program records from the Robotic Systems Joint Projects Office (RSJPO).

2. Conduct an analysis that describes the impact that DARPA has had on the overall UGV program. This research should place a majority of the emphasis on the effects to the UGV community following the DARPA Grand Challenges.

3. Create a case study on the Man Transportable Robotic System (MTRS) program. This case would involve tracing the history of the PackBot and TALON robots. The case should present the story of how these two small companies fielded two of the most well-known robots in the U.S. military.

4. Conduct research on storage of UGVs at the end of a conflict. Examine the process for warfighters to access this equipment at the beginning of another conflict. How does the warfighter find out what equipment is in storage? Is this process efficient, and are there improvements that can be made to this system?

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