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**TECHNOLOGY FOR SPACE STATION EVOLUTION
- A WORKSHOP**

ROBOTICS TECHNOLOGY DISCIPLINE

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TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

- TECHNOLOGIES ARE USUALLY ASSESSED BY THE SAME AGENCIES THAT PROMOTE THEM.
- THE HIDDEN ASSUMPTION ALWAYS FAVORS THE STATUS QUO.
- TECHNOLOGY ASSESSMENTS RARELY RAISE THE IMPORTANT ISSUES.

FROM SULLIVAN, "PUBLIC INTEREST LAUNDRY LIST FOR TECHNOLOGY ASSESSMENT: TWO DOZEN ETERNAL TRUTHS ABOUT PEOPLE AND TECHNOLOGY," TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE, VOL. 8(4), 1975

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

TECHNOLOGY DISCIPLINE SUMMARY FOR ROBOTICS

FOUR TECHNOLOGY CATEGORIES

- **CROSS-CUTTING, SYSTEM WIDE**
 - SYSTEMS ENGINEERING PROCESSES FOR INTEGRATED ROBOTICS
 - MAN/MACHINE COOPERATIVE CONTROL
 - THREE-DIMENSIONAL REAL-TIME PERCEPTION
- **ADVANCED RESEARCH**
 - MULTIPLE-ARM REDUNDANCY CONTROL
 - MANIPULATOR CONTROL FROM A MOVABLE BASE
 - MULTIPLE-AGENT REASONING AND VERIFICATION OF AUTOMATED FUNCTIONS*
- **APPLICATION-SPECIFIC**
 - MECHANISMS
 - SENSORS
- **OTHER**
 - TECHNOLOGIES REVIEWED, MERGED, OR DROPPED
 - TECHNOLOGIES OVERLOOKED

* ALSO REPRESENTS AUTOMATION TRACK

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS

MECHANISMS

BACKGROUND

SCOPE:

- THE POSSIBILITY OF LOCAL CONTROL AND DISTRIBUTED PROCESSING ARCHITECTURES WILL DRIVE THE DESIGN OF COMPONENTS SUCH AS END EFFECTOR, JOINTS, ARM, ETC. INTEGRAL COOLING, LOCAL POWER SOURCES, POWER TO WEIGHT ARE TYPICAL AREAS REQUIRING EXTENSIVE INVESTIGATION. THE CONCERN FOR POWER CONSUMPTION, HEAT DISSIPATION, ETC., AFFECT THE DESIGN OF ROBOT MOTORS TO THE EXTENT THAT ENTIRE NEW TECHNOLOGIES MAY BE REQUIRED (E.G. SUPERCONDUCTORS).

OBJECTIVES:

- TO DEVELOP A RESEARCH INITIATIVE THAT DEALS WITH THE SPACE ROBOT AT A SYSTEM LEVEL IN THE AREA OF MECHANISMS
- TO EXAMINE AND ITEMIZE THE ENTIRE SPECTRUM OF PHYSICAL TASKS, NUMERICAL VALUES, FREQUENCY, AND LACK OF STRUCTURE ENVISIONED, AND DETERMINE THE AVAILABILITY OF EXISTING MECHANISMS TO MEET THESE NEEDS AND TO PROVIDE SOLUTIONS TO PROBLEM AREAS YET UNRESOLVED
- DEVELOP A UNIVERSAL MANUAL CONTROLLER WITH VERSATILE EMBEDDED DECISION MAKING SOFTWARE FOR HUMAN PERFORMANCE ENHANCEMENT AND THE OPERATION OF A FULL SPECTRUM OF SLAVE MANIPULATORS
- DEVELOP A SYSTEM HARDWARE AND SOFTWARE TECHNOLOGY TO PURSUE UNSTRUCTURED TASKS CONTAINING DISTURBANCES AND STILL REQUIRE PRECISION--A SOPHISTICATED MODELING-CONTROL OBJECTIVE
- DEVELOP ADVANCED MODULAR ROBOT ARCHITECTURES WHOSE STANDARDIZED MODULES CAN BE USED TO ASSEMBLE A FULL SERIES OF PROTOTYPES, i.e., A DESIGN INFRASTRUCTURE

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS

MECHANISMS

BACKGROUND CONTINUED

OBJECTIVES:

- DEVELOP A PRIME MOVER OF EXCEPTIONALLY LIGHTWEIGHT, HIGH RESOLUTION, AND HIGH STIFFNESS TO MAKE THE GENERALIZED ARCHITECTURE OF ROBOT MANIPULATORS FEASIBLE
- TO FURTHER PROVIDE DESIGNS COMPATIBLE WITH THE TOOLING USED FOR HUMAN EVA AND TO DEVELOP STANDARDIZED INTERFACES FOR BOTH MAN AND MACHINE WHERE APPLICABLE. THE KNOWLEDGE BASE PROVIDED BY THIS RESEARCH WILL DEFINE THE MATERIALS, MOTORS, TOOLING, THERMAL COMPONENTS, AND SYSTEMS CONCEPTS NEEDED IN THIS AREA.
- DEVELOP RECOGNIZED NUMERICAL REQUIREMENTS TO MEET SCENARIOS FOR UNEXPECTED EVENTS (PERHAPS 40% OF THE ACTUAL WORKLOAD).

REQUIREMENTS:

- CURRENT MECHANISM DESIGN DOES NOT ADEQUATELY SUPPORT THE DEVELOPMENT OF A ROBOT OPERATING IN THE 0-G AND VACUUM OF SPACE.
- THE POWER-TO-WEIGHT, POWER CONSUMPTION AND THERMAL RESTRICTIONS IMPOSED BY THE SPACE ENVIRONMENT ARE DRIVING FORCES IN THE DESIGN OF ANY MECHANISM IN SPACE, BUT THEY ARE MAGNIFIED WHEN APPLIED TO A ROBOT EXPECTED TO PERFORM A MYRIAD OF TASKS IN AN UNSTRUCTURED ENVIRONMENT.
- CURRENT MECHANISMS NEED TO BE ADAPTED FOR SPACE USE
 - LIGHTER MATERIAL
 - REDUCE OVERALL WEIGHT
 - REDUCE SIZE
 - INTERFACES ADAPTED FOR ROBOTICS USE

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS

MECHANISMS

BACKGROUND CONTINUED

REQUIREMENTS (CONTINUED):

- NEW MECHANISMS ARE REQUIRED FOR TASKS THAT MAN CANNOT DO IN SPACE.
- EVA TOOLS NEED TO BE MODIFIED FOR ROBOTIC INTERFACE.
- PNEUMATIC TOOLS ARE NEEDED.
- LATCHING DEVICES CAPABLE OF HOLDING LARGE COMPONENTS, STRUCTURES OR APPENDAGES ARE NEEDED.
- POWER TOOLS FOR ROBOTICS USE
 - DRILL
 - WRENCHES
 - WINCH/HOIST (SPACE CRANE)
- PRECISION LIGHT SOURCES ARE NEEDED.
- DUAL GRASPING TOOLS ARE NEEDED.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MECHANISMS

PROGRAM PLAN

APPROACH:

- NASA AND THE AEROSPACE COMMUNITY HAVE ONGOING RESEARCH EFFORTS IN THE AREA OF SPACE MATERIALS, STRUCTURES AND MECHANISMS. HOWEVER, THIS INITIATIVE WOULD PROVIDE A FOCUS OF THESE EFFORTS IN THE AREA OF ROBOTICS. IT WOULD DEVELOP A FOCAL POINT FOR THE INTEGRATION OF THE LATEST TECHNICAL ADVANCES IN MECHANISMS AS THEY APPLY TO SPACE ROBOTICS. THE INITIATIVE WOULD DETERMINE THE AREAS REQUIRING MORE CONCENTRATED RESEARCH AND ATTACK THESE PROBLEMS IN AN AGGRESSIVE MANNER TO PROVIDE TIMELY SOLUTIONS FOR SPACE STATION FREEDOM.

DELIVERABLES:

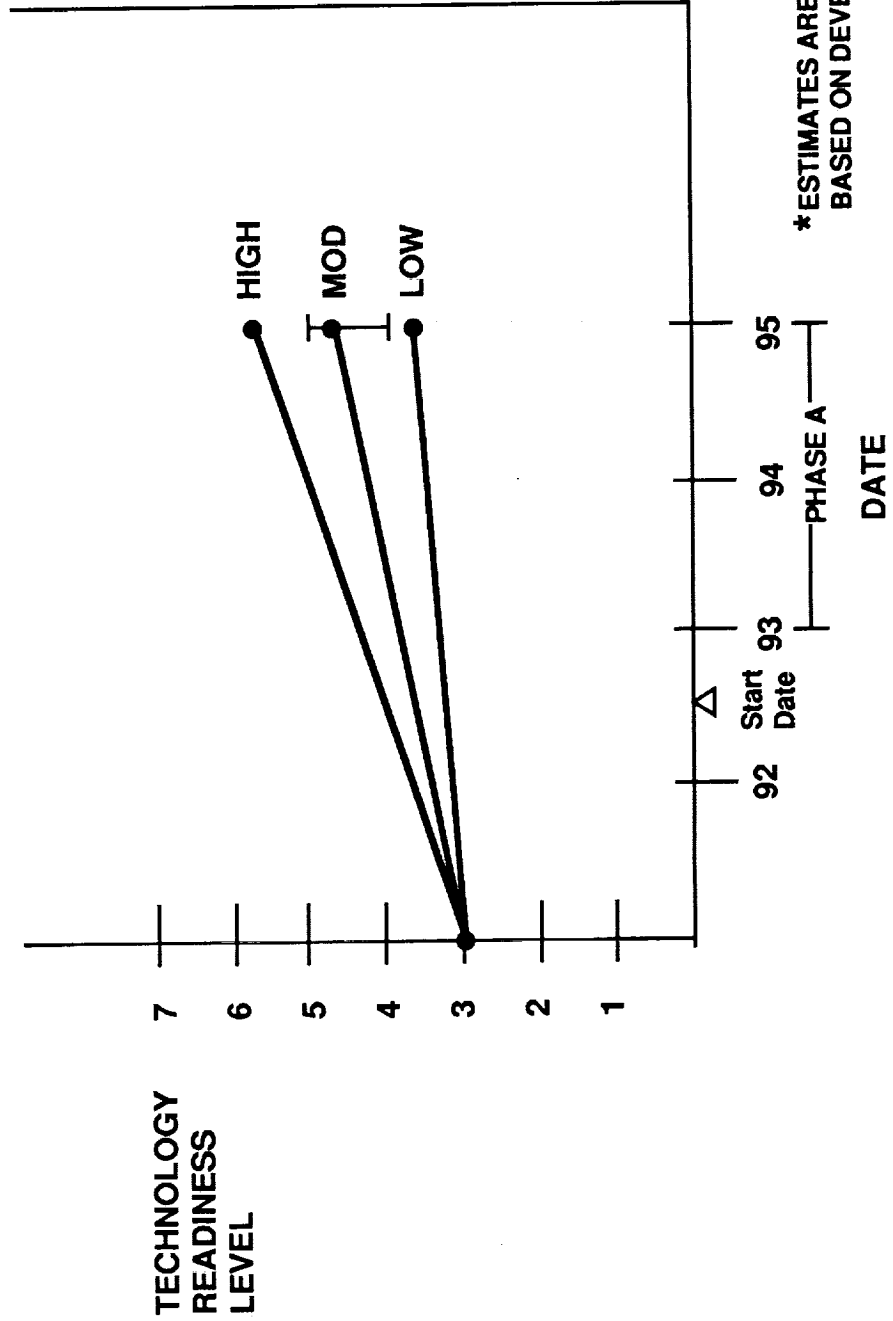
- A ROBOT SYSTEMS DEFINITION INCORPORATING THE DESIGN CRITERIA DETERMINED TO BE THE LATEST AVAILABLE, AND A FORECAST OF TECHNICAL IMPROVEMENTS ON THE HORIZON WITH THEIR PROJECTED AVAILABILITY
- A DEMONSTRATION ROBOT SYSTEM INCORPORATING THE MECHANISM CURRENTLY UNDER DEVELOPMENT AND ASSESSMENT CRITERIA FOR THE COMPONENT TEST EVALUATION
- INTERFACE DEFINITION FOR ELECTRICAL AND MECHANICAL COMPONENTS IN THIS ARENA

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

MECHANISMS

ROBOTICS TECHNOLOGY DISCIPLINE

TECHNOLOGY ASSESSMENT*



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

SENSORS

BACKGROUND

SCOPE:

- ENHANCEMENT IN SENSOR TECHNOLOGY IS REQUIRED TO IMPROVE THE CAPABILITIES FOR SAFE AND EFFECTIVE TELEROBOTIC OPERATION IN THE SPACE STATION ENVIRONMENT. THIS AREA INCLUDES ALL THE MEANS, PASSIVE AND ACTIVE, BY WHICH THE HUMAN TELEOPERATOR, OR LATER, THE SEMI-AUTONOMOUS ROBOT, COLLECTS INFORMATION ABOUT THE ENVIRONMENT.

OBJECTIVES:

- IT IS NECESSARY TO DEVELOP A SENSOR PACKAGE THAT WOULD FACILITATE THE SAFE AND SUCCESSFUL OPERATION OF A ROBOTIC SYSTEM IN THE SPACE STATION ENVIRONMENT. TO ACCOMPLISH THIS THE SENSORS MUST PROVIDE NAVIGATION, COLLISION, AND OBJECT MAINTENANCE GUIDANCE. THESE SENSORS SHALL PROVIDE MACHINE VISION WITH HIGH RESOLUTION CAPABILITY; LASERS FOR CLOSE PROXIMITY RANGING; FORCE/TORQUE AND CONTACT SENSING; AND SPECIALIZED SENSORS SUCH AS ULTRASONIC SENSORS.

REQUIREMENTS:

- PRESENT SENSOR TECHNOLOGIES PLACE LIMITS ON THE CAPABILITIES OF SPACE TELEOPERATION AND ON THE DEVELOPMENT OF ROBOTS WITH INCREASING AUTONOMY. SENSORS MUST BE IMPROVED TO SUPPORT SAFE OPERATIONS IN MORE CHALLENGING, UNSTRUCTURED ENVIRONMENTS AND TO ALLOW TELEROBOTIC SYSTEMS TO ACCOMPLISH A WIDER VARIETY OF TASKS TO REPLACE, AND EVENTUALLY EXCEED, EVA CAPABILITIES. SPECIALIZED SENSORS MUST BE DEVELOPED FOR THE MICROGRAVITY IVA AND VACUUM SPACE ENVIRONMENTS TO ENABLE SPECIFIC INSPECTION, DIAGNOSIS AND REPAIR TASKS.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

SENSORS

ROBOTICS TECHNOLOGY DISCIPLINE

PROGRAM PLAN

APPROACH:

- IN CONJUNCTION WITH OTHER AREAS, DEVELOP A DATABASE OF TELEROBOTIC ACTIVITIES AND TASKS REQUIRED FOR SPACE STATION AND HUMAN EXPLORATION MISSIONS, AND REFINE THE INFORMATION TO FOCUS ON SENSOR REQUIREMENTS. IDENTIFY SPECIFIC TASKS THAT MAY REQUIRE SPECIALIZED SENSORS.
- CONTINUE THE DEVELOPMENT OF MACHINE VISION TECHNOLOGIES FOR A VARIETY OF SPACE TELEROBOTIC OPERATIONS.
- CONTINUE THE DEVELOPMENT OF FORCE/TORQUE AND CONTACT SENSORS FOR A VARIETY OF SPACE TELEROBOTIC OPERATIONS.
- DEVELOP SENSOR PACKAGES TO ENABLE SAFE PROXIMITY OPERATIONS, GRAPPLING, TRANSLATION, COLLISION AVOIDANCE, AND WORKSPACE OPERATIONS IN COMPLEX UNSTRUCTURED ENVIRONMENTS.
- DEVELOP SPECIALIZED SENSORS FOR EXTERNAL ROBOTS FOR THE INSPECTION, DIAGNOSIS, AND REPAIR OF MALFUNCTIONING EQUIPMENT IN THE SPACE ENVIRONMENT INCLUDING LEAK DETECTORS, INTERROGATION, ULTRASONIC, AND OTHER NDT INSPECTION SENSORS.
- DEVELOP SPECIALIZED SENSORS FOR IVA ROBOTS INCLUDING ATMOSPHERIC SAMPLERS AND AUDIO SENSORS.

DELIVERABLES:

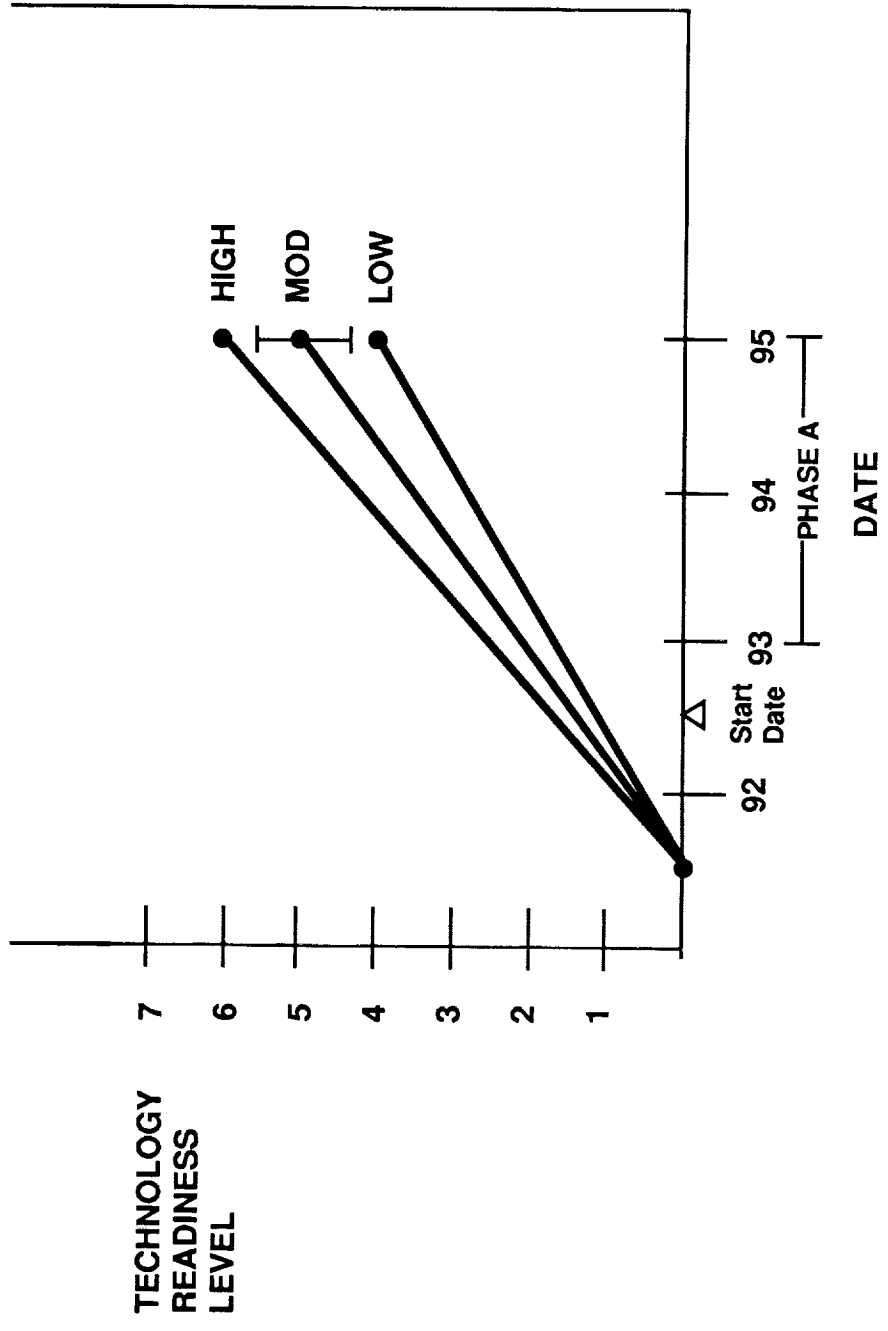
- A GROUND TEST/DEMONSTRATION WHICH SHOWS THE FUNCTIONAL ASPECTS OF THE TRADE STUDY SELECTED SENSORS FOR ROBOTIC NAVIGATION, COLLISION AVOIDANCE, AND OBJECT MAINTENANCE. OBJECT MAINTENANCE SENSORS WILL BE CHOSEN BASED ON NEEDS AT THE TIME.
- FLIGHT DEMONSTRATION SAME AS NUMBER 1. THIS CAN BE ACCOMPLISHED USING AN EXISTING PROGRAM, SUCH AS \bar{S} , WITHOUT HINDERING THE PROGRAM.
- FLIGHT SENSORS SHOULD BE AVAILABLE FOR INTEGRATION BY THE FIRST SPACE STATION FREEDOM FLIGHT.
- OTHER FUNCTIONS MAY BE REQUIRED.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

SENSORS

ROBOTICS TECHNOLOGY DISCIPLINE

TECHNOLOGY ASSESSMENT



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY
DISCIPLINE

SYSTEMS ENGINEERING PROCESSES
FOR INTEGRATED ROBOTICS

BACKGROUND

SCOPE:

- DEVELOP AN ON-GOING PROGRAM FOR THE SYSTEMS-LEVEL ENGINEERING OF SPACE ROBOTICS, ENCOMPASSING THE INTERNAL ARCHITECTURE, INTERACTION WITH THE EXTERNAL TASK AND ENVIRONMENT, AND WITH PARTICULAR EMPHASIS ON THE INTERACTION WITH HUMANS, BOTH CONTROLLING AND AT THE WORK SITE

OBJECTIVES:

- UNDERSTAND THE INTERRELATIONSHIPS BETWEEN COMPONENT TECHNOLOGIES AND TELEROBOT CAPABILITIES.
- IDENTIFY THE KEY TASKS IN THE INTEGRATION OF COMPONENT TECHNOLOGIES INTO FULLY CAPABLE TELEROBOTIC SYSTEMS.
- DEVELOP A QUANTITATIVE DATA BASE ON TELEROBOTIC CAPABILITIES OVER A VARIETY OF TYPICAL SPACE TASKS.
- DEVELOP LABORATORIES CAPABLE OF QUICKLY TESTING NEW CONCEPTS IN SPACE HARDWARE TO EVALUATE COMPATIBILITY WITH TELEROBOTIC OPERATIONS.
- HAVE A QUANTITATIVE BASIS FOR CRITICAL TRADE STUDIES BETWEEN TELEROBOTIC CAPABILITIES AND PROGRAM REQUIREMENTS.
- HAVE A PATHWAY FOR DEVELOPMENT OF INNOVATIVE TECHNOLOGIES.
- BETTER UNDERSTAND INTERFACES (PARTICULARLY TOOLS AND END EFFECTORS) BETWEEN TELEROBOTICS AND TASKS.
- STUDY THE POTENTIAL INTERACTIONS BETWEEN TELEROBOTS AND HUMANS IN SPACE (BOTH EVA AND IVA), AIMED AT DEVELOPING AND REVIEWING STANDARDS FOR THE DESIGN OF JOINT HUMAN/TELEROBOTIC WORKSITES.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY
DISCIPLINE

SYSTEMS ENGINEERING PROCESSES
FOR INTEGRATED ROBOTICS

BACKGROUND (CONTINUED)

RATIONALE:

- IT IS NOT SUFFICIENT TO STUDY TELEROBOTIC TECHNOLOGIES WITHOUT UNDERSTANDING HOW THESE TECHNOLOGIES COME TOGETHER TO FORM A ROBOT SYSTEM, OR HOW THE TELEROBOT INTERACTS WITH CURRENTLY PLANNED OR POTENTIAL FUTURE SPACE APPLICATIONS

REQUIREMENT:

- A PRELIMINARY REQUIREMENTS DEFINITION IS REQUIRED TO REDUCE LIFE-CYCLE COST.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

SYSTEMS ENGINEERING PROCESSES
FOR INTEGRATED ROBOTICS

PROGRAM PLAN

APPROACH:

- NASA SHOULD CONTINUE THE ESTABLISHMENT OF MULTI-PURPOSE TEST BEDS TO USE FOR DEVELOPING NECESSARY DATA BASES FOR TELEROBOTICS SYSTEMS ANALYSIS. THIS SHOULD INCLUDE BOTH TESTBEDS FOR DEVELOPING SYSTEMS INTEGRATION OF TECHNOLOGIES INTO TELEROBOT SYSTEMS, AND SYSTEMS STUDIES OF THE APPLICATIONS OF TELEROBOTICS TO CURRENT AND FUTURE TASKS, INCLUDING APPROPRIATE SIMULATION OF THE SPACE ENVIRONMENT. ATTENTION MUST BE PAID TO RECONFIGURABLE ARCHITECTURES, RAPID PROTOTYPING, AND TASK APPLICATIONS DRAWN FROM THE SPECTRUM OF CURRENT AND POTENTIAL FUTURE TELEROBOTIC REQUIREMENTS IN SPACE.

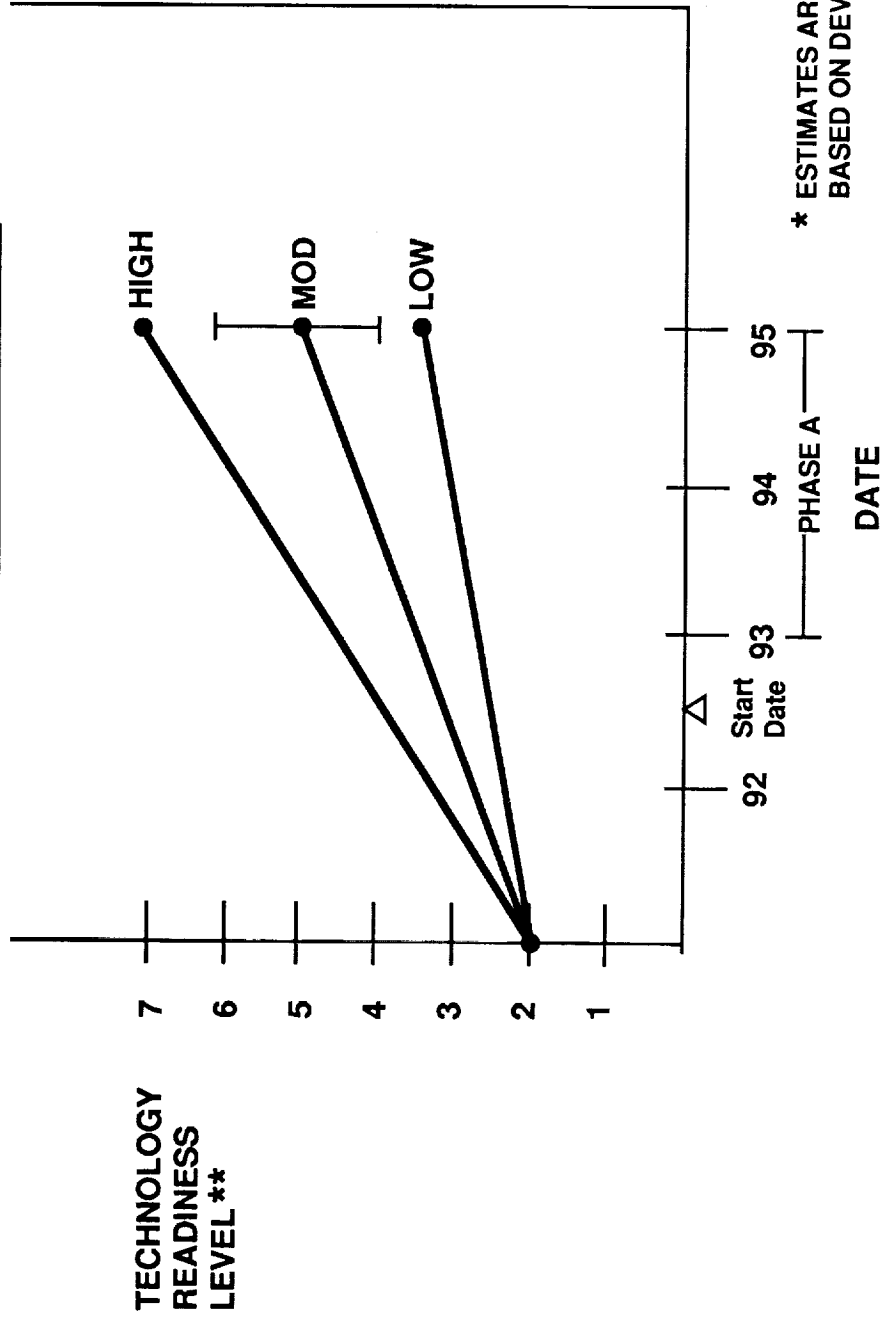
DELIVERABLES:

- QUANTITATIVE DATA BASE ON TELEROBOTIC CAPABILITIES AND LIMITATIONS, CROSS-INDEXED AGAINST ROBOTIC COMPONENT TECHNOLOGIES
- DEVELOPMENT OF A REFERENCE STANDARD FOR SPACECRAFT DESIGNERS FOR EVA/TELEBOTIC INTERFACES FOR SERVICING
- DESIGN OF A STANDARD TOOL AND INTERFACE SET, WITH EMPHASIS ON TOOL SYSTEMS COMPATIBLE WITH BOTH EVA AND TELEROBOTIC SYSTEMS
- SIMULATION FACILITIES FOR USE IN ASSESSING TELEROBOTIC CAPABILITIES AS PART OF THE DEVELOPMENT PROCESS FOR FUTURE SPACECRAFT
- DEVELOPMENT OF A KNOWLEDGE BASE ON THE INTEGRATION OF COMPONENT TECHNOLOGIES INTO FUNCTIONAL, ROBUST TELEROBOTIC SYSTEMS

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE SYSTEMS ENGINEERING PROCESSES
FOR INTEGRATED ROBOTICS

TECHNOLOGY ASSESSMENT*



* ESTIMATES ARE APPROXIMATE AND
BASED ON DEVELOPMENT PLAN

** FOR UNBUILT SYSTEMS

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MAN/MACHINE
COOPERATIVE CONTROL

BACKGROUND

SCOPE:

- MAN-MACHINE COOPERATIVE CONTROL REFERS TO THE DEVELOPMENT, IMPLEMENTATION, AND VALIDATION OF METHODOLOGIES BY WHICH MAN AND ROBOT(S) CAN PERFORM REQUIRED TASKS IN CONCERT. SUCH TASKS CAN BE PERFORMED DIRECTLY BY MAN, REMOTELY BY MAN (TELEOPERATION), DIRECTLY BY MACHINE UNDER OPERATOR SUPERVISION, AND JOINTLY BY MAN AND MACHINE (SHARED CONTROL). HUMAN FACTORS TASK ALLOCATION AND SYSTEM PERFORMANCE CONSIDERATIONS ARE EXPLICITLY INCLUDED AS WELL AS CONSISTENT UPDATE OF WORLD MODELS, PERFORMANCE MONITORING, AND SAFETY.

OBJECTIVES:

- ULTIMATELY OFF-LOAD AS MUCH WORK AS POSSIBLE TO THE ROBOT.
- USE THE RESOURCES OF ALL SYSTEM AGENTS APPROPRIATELY.
- BE ABLE TO FLUIDLY TRANSITION BACK AND FORTH AMONG AGENTS (TRADED CONTROL).

RATIONALE:

- DIRECT TELEOPERATED CONTROL OF IMPORTED ROBOTIC FUNCTIONS (E.G., ORU CHANGEOUT VIA GROUND CONTROL) IS SLOW, TEDIOUS, AND PRONE TO ERROR. DIFFICULTIES ABOUND IN COMPREHENSIVELY OBSERVING THE WORK SPACE; DERIVING A SUITABLE 3-D SENSE OF POSITION, FORCE, AND ORIENTATION; AND DEALING WITH TIME DELAYS. FULL AUTONOMY FOR HIGHLY COMPLEX INTERACTIONS WILL BE SLOW IN FORTHCOMING. THEREFORE, THE FULL COOPERATION BETWEEN MAN AND ROBOT (PERFORMING SPECIFIC AUTONOMOUS OPERATIONS) IS ESSENTIAL FOR FEASIBILITY, EFFICIENCY, AND FAIL-SAFE ASSURANCE OF THE COMPLETE OPERATION.

REQUIREMENT:

- A PRELIMINARY REQUIREMENTS DEFINITION IS NEEDED FOR PRODUCTIVITY ENHANCEMENT.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MAN/MACHINE
COOPERATIVE CONTROL

PROGRAM PLAN

APPROACH:

- ESTABLISH TESTBED AND ASSOCIATED SPACE RELATED SCENARIOS OF INTEREST.
- DEVELOP CAPABILITY TO PERFORM REQUIRED PRIMITIVE OPERATIONS (E.G., MOVE, GRASP, INSERT, FIND, ETC.) BOTH THROUGH TELEOPERATION, AUTONOMOUS OPERATION, SHARED OPERATION, ETC. THIS IS A MAJOR SYSTEMS INTEGRATION ACTIVITY.
- BASED ON PERFORMANCE INDICATORS, DETERMINE APPROPRIATE MIX OF RESOURCE UTILIZATION FOR A VARIETY OF SCENARIOS WHICH SPAN THE RANGE OF ROBOTIC OPERATIONS OF INTEREST.

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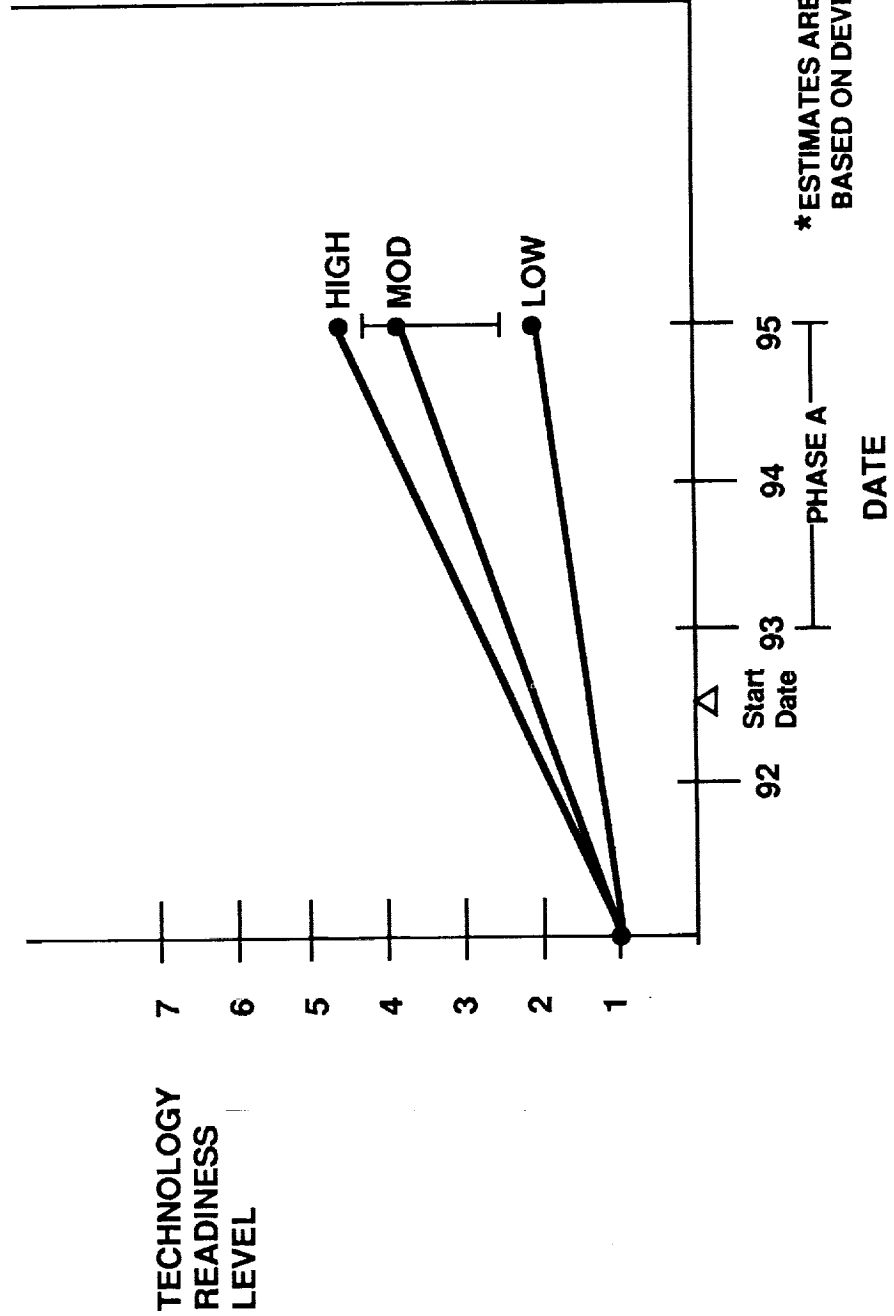
- A DEMONSTRATED CAPABILITY TO SMOOTHLY TRANSITION TASKS BETWEEN DIRECT OPERATOR CONTROL AND AUTONOMOUS OPERATION
- A DATA BASE WHICH GUIDES THE SUITABILITY OF TASK ALLOCATION FOR A VARIETY OF FUNCTIONS

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MAN/MACHINE COOPERATIVE CONTROL

TECHNOLOGY ASSESSMENT*



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

3D - REAL-TIME
MACHINE PERCEPTION

BACKGROUND

SCOPE:

- 3D-REAL-TIME MACHINE PERCEPTION REFERS TO MACHINE COGNITIVE PROCESSES WHICH CAN EXTRACT SENSORY DATA FROM VARIABLE ENVIRONMENTS IN REAL-TIME TO PROVIDE KNOWLEDGE ENABLING REAL-TIME INTERACTION WITH THE ENVIRONMENT, AND PLANNING AND REASONING ABOUT FUTURE ACTIVITIES.

OBJECTIVES:

- DEVELOP MEANS OF PROCESSING AND MANAGING THE ACQUISITION OF DATA FROM MULTIPLE SENSOR TYPES, USING CONVENTIONAL AND ALTERNATIVE PROCESSOR TECHNOLOGIES SUCH AS PARALLEL PROCESSORS AND NEURAL NETWORKS AS REQUIRED; INTEGRATING THE DATA TO BUILD AND VERIFY REPRESENTATIONS OF THE ROBOT'S ENVIRONMENT CONSISTING, NOT ONLY OF SPATIAL, BUT ALSO TEMPORAL, PROCEDURAL, FUNCTIONAL, AND OTHER INFORMATION; TO SUGGEST ROBOT INTERACTION WITH THE ENVIRONMENT BOTH FOR PURPOSES OF CLOSED LOOP CONTROL AND REASONING ABOUT CURRENT AND FUTURE ACTIVITIES.

RATIONALE:

- PRESENT MACHINE COGNITION SYSTEMS ARE LIMITED IN CAPABILITY TO PERFORMING SPECIALIZED FUNCTIONS IN CAREFULLY CONTROLLED ENVIRONMENTS. PROCESSING CAPABILITIES REQUIRED TO PERFORM THESE FUNCTIONS GENERALLY FAR EXCEED THOSE AVAILABLE TO IMPLEMENT REAL-TIME UTILIZATION OF SENSED DATA.

REQUIREMENT:

- OPERATIONAL CONSTRAINTS FOR PROXIMITY OPERATIONS, LIFE-CYCLE COST REDUCTIONS AND PRODUCTIVITY ENHANCEMENT DUE TO IMPROVED ROBOT PERFORMANCE

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

3D - REAL-TIME
MACHINE PERCEPTION

PROGRAM PLAN

APPROACH:

- DEVELOP ALGORITHMS AND PROCESSING ARCHITECTURE WHICH ENABLE THE EXTRACTION OF INFORMATION FROM SENSED DATA AND THE INTEGRATION OF INFORMATION FROM DIFFERENT DATA TYPES.
- DEVELOP MEANS OF REPRESENTING ENVIRONMENTAL INFORMATION IN A STRUCTURED MANNER, INCLUDING SPATIAL, FUNCTIONAL, PROCEDURAL, TEMPORAL, AND OTHER INFORMATION TYPES AND PROCESSES BY WHICH NEW INFORMATION CAN BE INTEGRATED INTO EXISTING MODELS AND CONFLICTING INFORMATION RATIONALIZED.
- INTEGRATE COGNITION PROCESSES WITH REASONING PROCESSES TO ENABLE DIRECTED ACQUISITION OF SENSORY INFORMATION ABOUT UNKNOWN ASPECTS OF THE ENVIRONMENT.

DELIVERABLES:

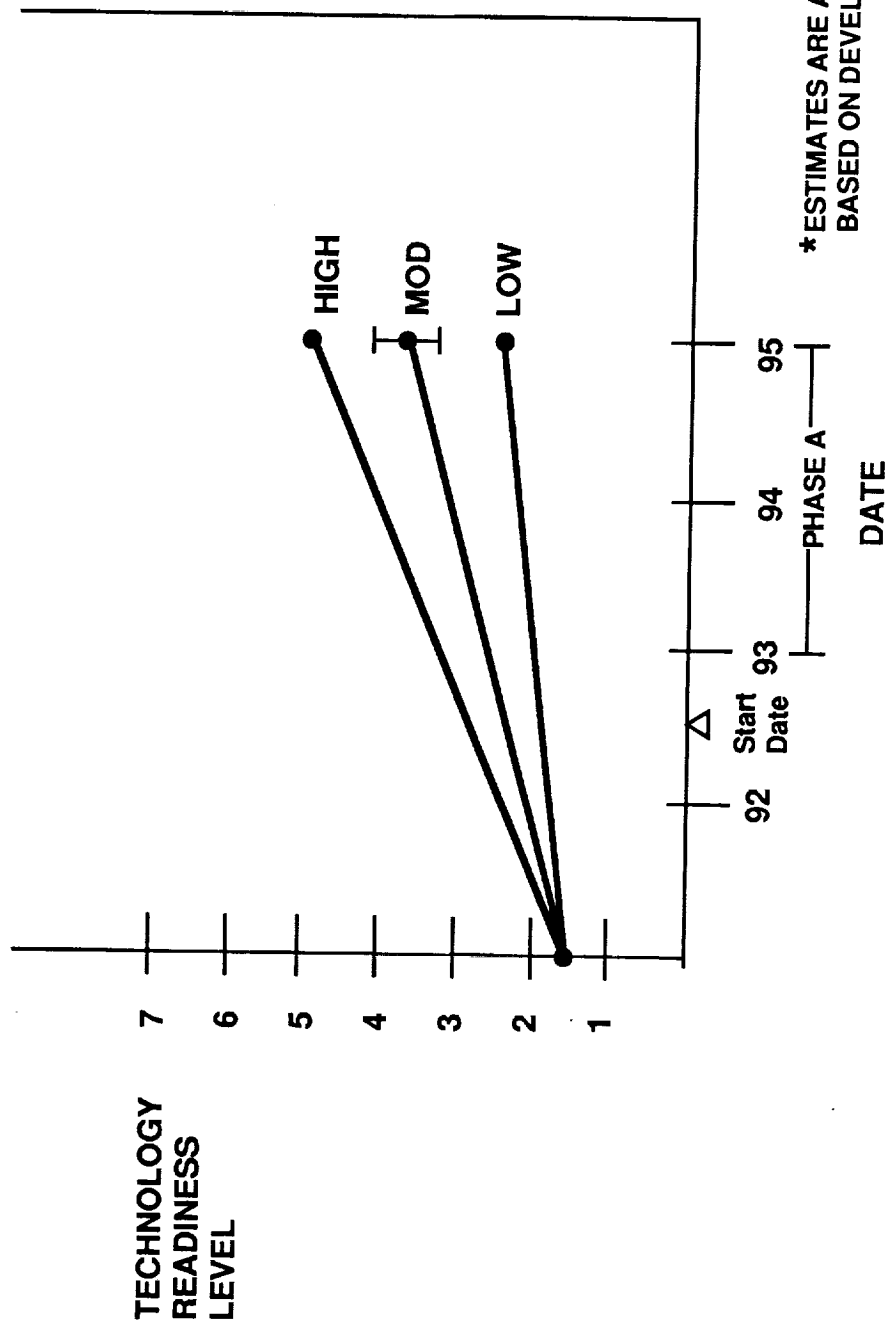
- A SELF-CONTAINED COGNITIVE PROCESSING SYSTEM UTILIZING DATA FROM GENERAL SENSORS CAPABLE OF DEVELOPING ENVIRONMENTAL MODELS, WHICH INTERFACES WITH CONVENTIONAL COMPUTING SYSTEMS
- A DEMONSTRATION SYSTEM USING TWO OR MORE SENSOR TYPES TO BUILD ENVIRONMENTAL MODELS UTILIZED BY REAL-TIME CONTROL AND PLANNING SYSTEMS TO PERFORM A COMPLEX TASK IN A FLEXIBLE ENVIRONMENT

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

3D - REAL-TIME
MACHINE PERCEPTION

TECHNOLOGY ASSESSMENT*



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MULTIPLE ARM
REDUNDANCY CONTROL

BACKGROUND

SCOPE:

- MULTIPLE ARM REDUNDANCY CONTROL IS A METHOD OF EFFECTIVELY PLANNING AND CONTROLLING THE POSITIONING AND MOTION OF MULTIPLE MANIPULATOR ARMS TO SATISFY MULTIPLE OBJECTIVES BEYOND SIMPLE POSITIONING OF THE END-EFFECTORS.

OBJECTIVES:

- DEVELOP ROBUST AND COMPUTATIONALLY EFFICIENT ALGORITHMS FOR PLANNING AND CONTROLLING ADDITIONAL DEGREES-OF-FREEDOM TO SATISFY CERTAIN CRITERIA SUCH AS OBSTACLE AVOIDANCE, LIGHTING AND CAMERA-VIEWING POSITIONING; AND THE OPTIMIZATION OF OBJECTIVE FUNCTIONS INCLUDING JOINT VELOCITIES, POWER DISSIPATION, ACTUATOR TORQUES, CONTACT FORCES AND TORQUES, IMPEDANCE, SYSTEM MOMENTUM, AND DEXTERITY.

REQUIREMENTS:

- ADDITIONAL DEGREES-OF-FREEDOM ARE INHERENT TO MULTIPLE ARM ROBOTS AND MUST BE CONTROLLED IN SOME MANNER. THEY ARE ALSO EXTREMELY USEFUL IN OBTAINING OTHER GOALS THAT CAN CONFLICT WITH THE DESIRED POSITIONING OF THE END-EFFECTORS (SUCH AS COLLISION AVOIDANCE). FURTHERMORE, COORDINATION BETWEEN THE MULTIPLE ARMS MUST PROGRESS BEYOND THE CURRENT METHOD OF INDEPENDENTLY CONTROLLING EACH ARM (RMS W/FTS ATTACHED).

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MULTIPLE ARM
REDUNDANCY CONTROL

PROGRAM PLAN

APPROACH:

- STUDY AND SELECT MANIPULATION OBJECTIVES TO BE HANDLED BY REDUNDANT DEGREES-OF-FREEDOM.
- DEVELOP ALGORITHMS TO SATISFY THESE MANIPULATION OBJECTIVES.
- SELECT AN EXPERIMENTAL SYSTEM ON WHICH TO IMPLEMENT THESE ALGORITHMS. TUNE AND OPTIMIZE THE ALGORITHMS FOR THIS SPECIFIC SYSTEM.

DELIVERABLES:

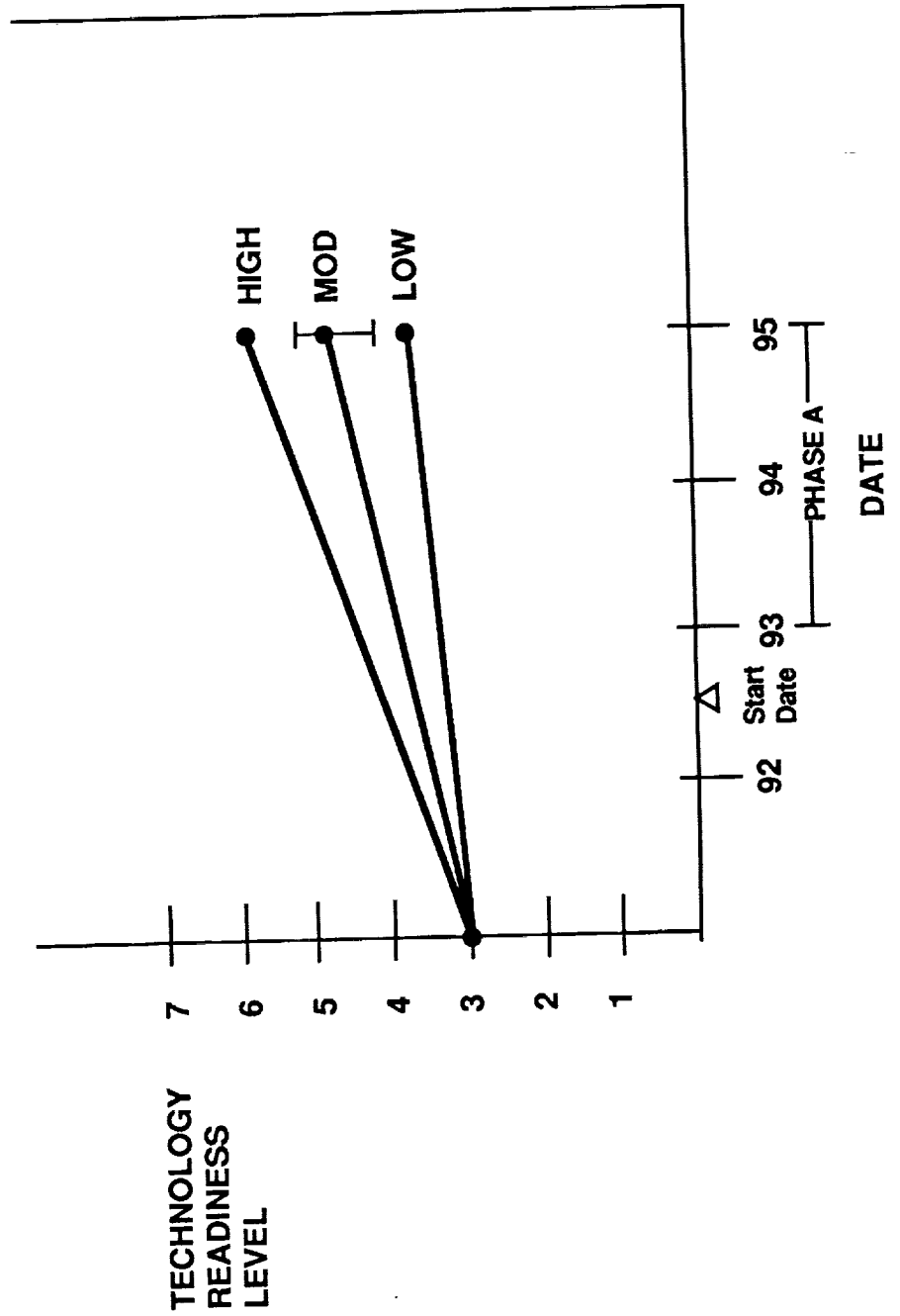
- COMPREHENSIVE STUDY OF WHAT OBJECTIVES TO HANDLE AND HOW TO IMPLEMENT THEM
- MULTIPLE ARM REDUNDANCY CONTROL ALGORITHMS
- DEMONSTRATION OF ORU CHANGE-OUT USING MULTIPLE ARMS WHILE SATISFYING OBSTACLE AVOIDANCE, CONTACT FORCE MINIMIZATION, ETC., USING FTS OR SPDM-CLASS ROBOT

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

MULTIPLE-ARM
REDUNDANCY CONTROL

ROBOTICS TECHNOLOGY DISCIPLINE

TECHNOLOGY ASSESSMENT



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MANIPULATOR CONTROL
FROM A MOVABLE BASE

BACKGROUND

SCOPE:

- MANIPULATOR CONTROL FROM A MOVABLE BASE REFERS TO AN ADAPTIVE MANIPULATOR/VEHICLE SYSTEM THAT IS ABLE TO ACTIVELY ACCOMMODATE CHANGING TASK-BASE RELATIONSHIPS IN REAL-TIME WHILE AVOIDING COLLISIONS AND INSURING A STABLE COUPLED FREE-FLYER/TASK SYSTEM.

OBJECTIVE:

- DEVELOP TECHNOLOGY ALLOWING MANIPULATION PERFORMED FROM A FREE-FLYING BASE WHICH IS SAFE AND WITHOUT ADVERSE EFFECT ON THE TASK PLATFORM.

RATIONALE:

- FREE-FLYING MANIPULATION WILL ALLOW ORU EXCHANGE AND REPAIR FUNCTIONS TO BE PERFORMED ON DELICATE STRUCTURES OR LOW-MASS SATELLITES WITHOUT DAMAGE OR EFFECTS TO THEIR ORBIT OR ATTITUDE. BY ALLOWING TASK-INDUCED FORCES TO BE REACTED THROUGH A HOLDING ARM WHILE SIMULTANEOUSLY AVOIDING INDUCING FORCES DUE TO TASK-BASE MOTION AND COMPENSATING FOR COUPLED TASK-BASE SYSTEM DYNAMICS, A FREE FLYER OF REAL MASS CAN PERFORM OPERATIONS WITHOUT ADVERSE AFFECT TO THE PLATFORM.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MANIPULATOR CONTROL
FROM A MOVABLE BASE

PROGRAM PLAN

APPROACH - MOVING BASE MANIPULATION WILL REQUIRE TECHNOLOGY THRUSTS IN THREE AREAS: (1) SENSING, (2) CONTROLS, AND (3) MECHANISM.

1. IN THE SENSING AREA, INVESTIGATION INTO REAL-TIME OBJECT TRACKING IN BOTH POSITION AND ORIENTATION WILL BE ESSENTIAL TO SUCCESS. THE QUESTION OF WHAT "REAL-TIME" IS MUST ALSO BE ADDRESSED. VIDEO RATES OF 30 Hz ARE NOT SUFFICIENT EXCEPT FOR SLOW REACTING TASKS (< 3 Hz).
2. IN THE CONTROLS ARENA, INVESTIGATION OF ADAPTIVE CONTROLS FOR A COMPLETE FREE FLYER (i.e., 2 MANIPULATORS AND VEHICLE) SHOULD BE STUDIED. OTHERWISE JOINT FRICTION AND OTHER NONLINEAR EFFECTS WILL RESULT IN UNEXPECTED MOTIONS. DYNAMIC EFFECTS BOTH DURING STATION KEEPING AND AT TASK CONTACT (A VERY NONLINEAR PROBLEM) WILL NEED TO BE INVESTIGATED AND MODELLED. TASK-MANIPULATOR CONTACT FORCES GENERATE TORQUES WHICH CAN EASILY CAUSE PERTURBATION OSCILLATIONS WHICH WILL NEED TO BE REACTED BY EITHER THE VEHICLE CONTROLS OR COUNTERING FF MOTIONS. COLLISION AVOIDANCE WILL NEED TO BE EXPANDED TO REAL-TIME REACTION RATES SINCE COUNTERACTING FORCES CAN EASILY LEAD TO COUPLED SYSTEM DYNAMICS AND MOTIONS WHICH ARE PHYSICALLY COLLIDED.
3. IN THE MECHANISM ARENA, COMPLIANT ARMS WITH HIGH-SPEED REACTION/RESPONSE WILL BE NECESSARY UNDER WORST CASE SCENARIOS TO PREVENT STATION AND/OR FF DAMAGE.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MANIPULATOR CONTROL
FROM A MOVABLE BASE

PROGRAM PLAN (CONTINUED)

DELIVERABLES:

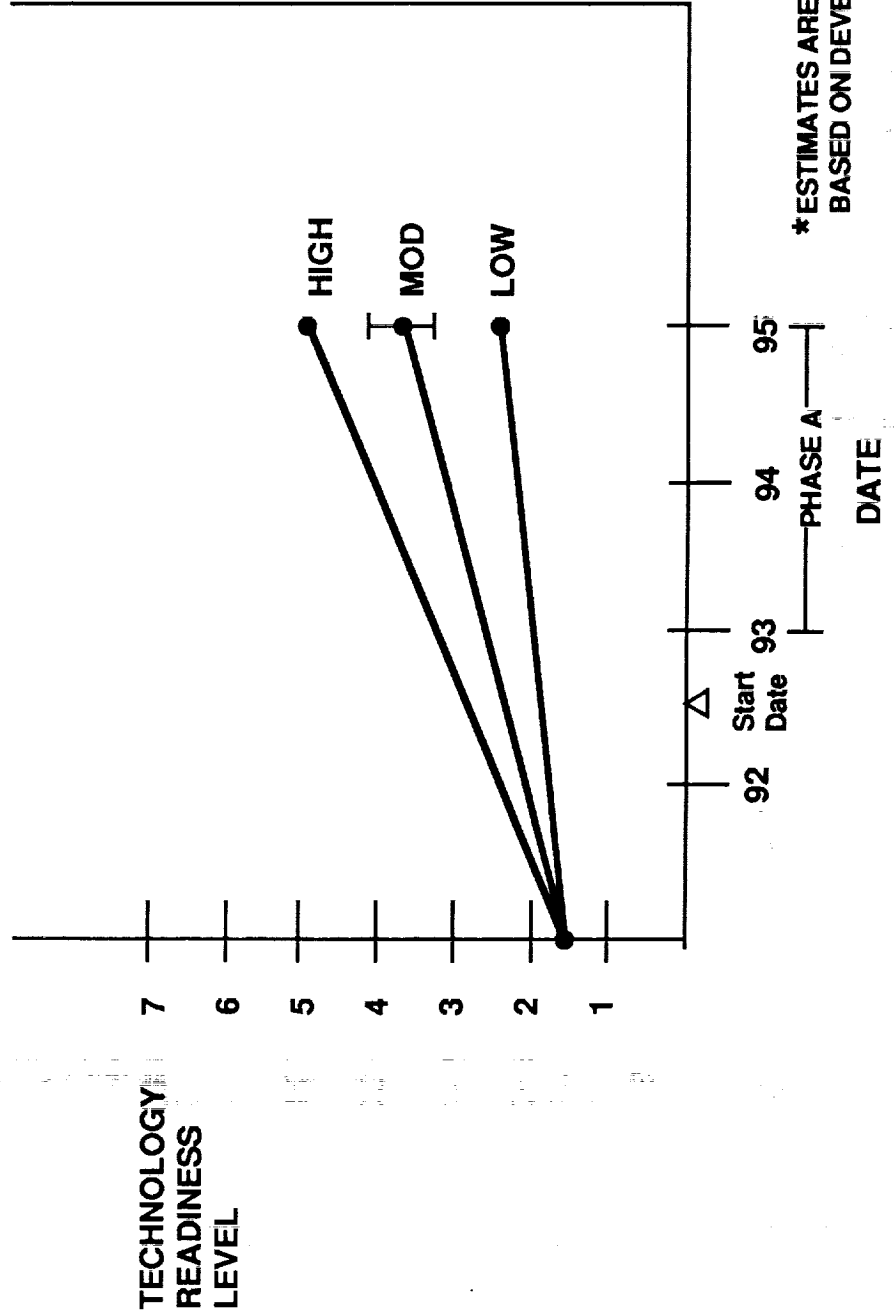
- FREE-FLYING TECHNOLOGY DEVELOPMENT IN THE AREAS OF SENSING, CONTROLS AND MECHANISMS. SPECIFICALLY:
 - REAL-TIME TASK-BASE RELATIONSHIP SENSOR SYSTEM
 - CONTROL ALGORITHMS FOR DYNAMIC COMPENSATION OF TASK-BASE MOTION
 - HIGH-SPEED COMPLIANT MECHANISMS FOR MANIPULATION
- A DEMONSTRATION OF FREE-FLYING MANIPULATION USING PENDULUM-LIKE TASKS AND ROBOTS
- A DEMONSTRATION OF FREE-FLYING MANIPULATION IN THE WET TANK AT MARSHALL USING BOTH ZERO BUOYANCY TASKS AND ROBOTS
- ACTIVE ACCOMMODATION OF FTS "FOOT" AS A DEMONSTRATION TEST FLIGHT

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MANIPULATOR CONTROL
FROM A MOVABLE BASE

TECHNOLOGY ASSESSMENT*



* ESTIMATES ARE APPROXIMATE AND
BASED ON DEVELOPMENT PLAN

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MULTI-AGENT REASONING

BACKGROUND

SCOPE:

- MULTI-AGENT REASONING REFERS TO AN ENVIRONMENT FOR ROBOTIC SYSTEMS PERFORMING UNDER VARYING DEGREES OF AUTONOMY TO ENGAGE IN INTERACTIVE AND COOPERATIVE ACTIVITIES.

OBJECTIVE:

- DEVELOP SYSTEMS AND METHODOLOGIES TO REASON ABOUT THE COOPERATIVE INTERACTION OF HETEROGENEOUS AGENTS, INCLUDING REASONING ABOUT EACH AGENT'S LOCAL ACTIVITY AS WELL AS THE INTEGRATED COMPOSITE ACTIVITY OF THE WHOLE ENVIRONMENT.

REQUIREMENTS:

- AGENTS OPERATING AUTONOMOUSLY, OR UNDER PARTIAL AUTONOMY, MUST PERFORM SOME LEVEL OF REASONING ABOUT THEIR ENVIRONMENT TO SYNTHESIZE DECISIONS ABOUT THEIR FUNCTIONS, AND HENCE WILL DRAW UPON A VARIETY OF INPUTS AND REASONING SCHEMES TO SYNTHESIZE THESE DECISIONS. IN ADDITION, MULTIPLE INTERACTIVE AGENTS REQUIRE REASONING WHICH CONSIDERS ACTIVITY ON A GLOBAL SCALE. THE DEGREE OF AUTONOMY EMPLOYED WILL VARY FROM SYSTEM TO SYSTEM, RESULTING IN THE INTERACTION OF MULTIPLE HETEROGENEOUS AGENTS. FOR COOPERATIVE MAN-MACHINE INTERACTION, THE REASONING RATIONALE USED BY AUTONOMOUS AGENTS MUST BE VERIFIED TO THE SATISFACTION OF HUMAN AGENTS DEPENDING ON THE AUTONOMY. THEREFORE, TECHNOLOGY MUST BE DEVELOPED TO REASON ABOUT ACTIVITIES FOR COOPERATING AGENTS OF VARYING LEVELS OF CAPABILITIES, AND TO VERIFY THE ASSOCIATED RATIONALE.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MULTI-AGENT REASONING

PROGRAM PLAN

APPROACH:

- DEVELOP PLANNING PROCESSES FOR SINGLE AGENTS AND MULTIPLE COOPERATIVE AGENTS AT BOTH TASK-SEQUENCE AND TASK-EXECUTION LEVELS
- DEVELOP METHODS FOR VERIFICATION OF PLANNING RATIONALE EMPLOYING MULTIPLE REASONING SCHEMES
- DEVELOP EXPLANATION FACILITIES FOR JUSTIFICATION OF PLANNING RATIONALE TO HUMAN AGENTS
- DEVELOP METHODS FOR DISTRIBUTING WORLD KNOWLEDGE AMONG MULTIPLE AGENTS, AND COOPERATIVELY SHARING THESE RESOURCES WHILE MAINTAINING INTEGRITY IN THE KNOWLEDGE
- DEVELOP TECHNIQUES FOR ACCOMMODATING UNCERTAINTIES AND ANOMALIES IN THE PLANNING ENVIRONMENT

DELIVERABLES:

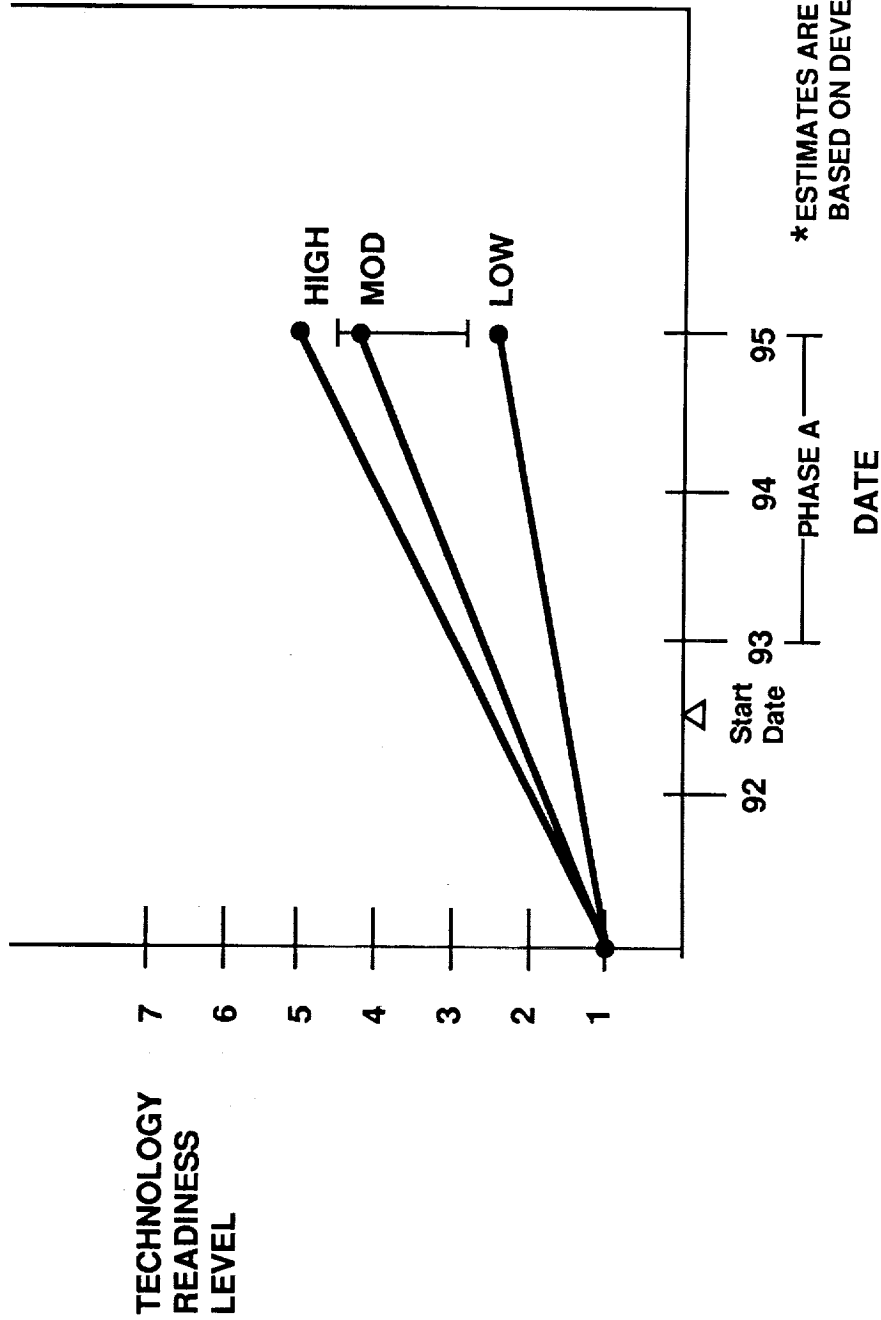
- ROBOTIC AGENTS WHICH CAN SEMI-AUTONOMOUSLY PLAN THEIR ACTIONS IN A RELATIVELY UNSTRUCTURED ENVIRONMENT, EXPLAIN/JUSTIFY RATIONALE USED IN DERIVING PLANS, AND COOPERATIVELY SHARE THOSE PLANS WITH OTHER AGENTS
- TECHNOLOGY DEMONSTRATIONS FOR DISTRIBUTED REASONING AND REPRESENTATION OF WORLD KNOWLEDGE

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE

MULTI-AGENT REASONING

TECHNOLOGY ASSESSMENT*



* ESTIMATES ARE APPROXIMATE AND
BASED ON DEVELOPMENT PLAN

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE SURFACING EVOLUTION TECHNOLOGIES

GOAL: TO PERFORM AUTONOMOUSLY, FAIL-SAFE TO HUMAN OPERATOR

REQUIREMENT: ROBUSTNESS

TASK: ORU CHANGEOUT FROM THE GROUND

SURVEY OF TASK REQUIREMENTS VERSUS TIME

1995-1999 ASSEMBLY COMPLETE	1996-2002 LUNAR MISSION	2006-2016 MARS MISSION
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- ASSEMBLY
- TRUSS
- UTIL TRAYS
- SIAS, PMADS
- ORU CHANGEOUT
- INSPECTION ASSEMBLY
- TRANSLATION
- MAINTENANCE
- EVA SUPPORT

- SOLAR DYNAMICS ASSEMBLY
- VEHICLE SERVICING AND REPAIR
- SATELLITE SERVICING
- PAYLOAD INTEGRATION
- IVA SUPPORT

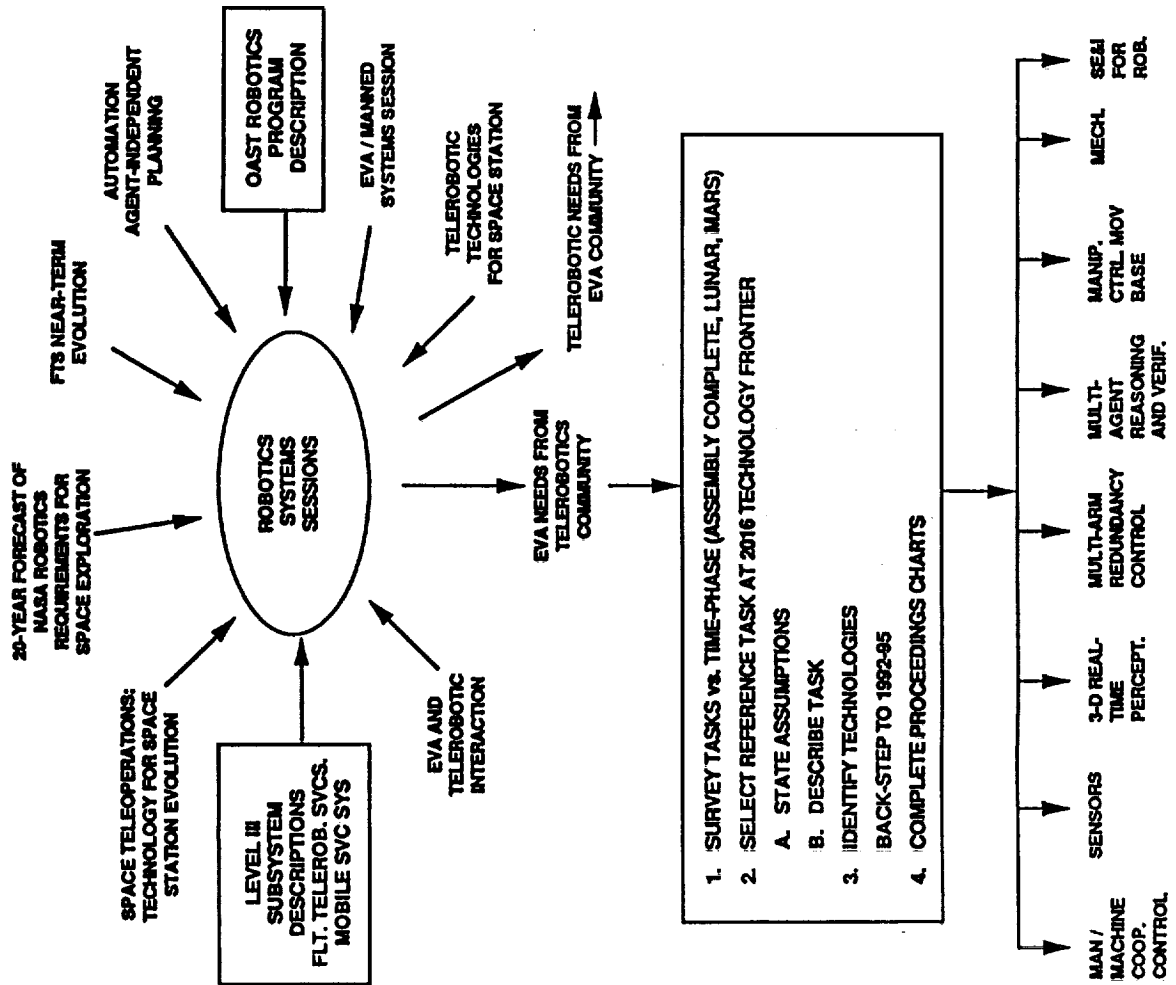
- ASSEMBLY
- SPACECRAFT
- AEROBRAKE
- LARGE CRYO TANK CHANGEOUT
- INSPECTION
- AUTONOMOUS BERTHING

ORU CHANGEOUT FROM THE GROUND
ASSUMPTIONS

- 2016+ TIME FRAME
- 3 SECOND VARIABLE TIME DELAY
- SSF ORU
- POSSIBLY UNKNOWN LOCATION OF FAILED ORU
- UNSTRUCTURED WORK ENVIRONMENT
- GROUND OPERATED SUPERVISORY CONTROL

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ROBOTICS TECHNOLOGY DISCIPLINE PROCESS DEFINITION FOR SURFACING TECHNOLOGY REQUIREMENTS



TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

RECOMMENDATIONS/ISSUES FOR ROBOTICS

- PROGRAM VS. TECHNOLOGY REQUIREMENTS
E.G., DO THIS → "REDUCE EVA BY 10% AND PERFORM THE SAME TASKS" (TECHNICAL)
NOT THIS → "GIVE ME THE REQUIREMENTS" (ORGANIZATIONAL)
- MORE INTERACTION BETWEEN EVA, ROBOTICS, AND SSF DESIGN COMMUNITIES
- IDENTIFY BENCHMARK TASKS AND MEASURES OF PRODUCTIVITY
- ALLOCATE SOME CONTINUING PORTION OF STS, MFTS, AND SPDM TO RESEARCH/TESTING
- TO OBTAIN SOME DEGREE OF GROUND CONTROL OR REMOTE MANIPULATION FOR SSF SUPPORT OF LUNAR AND MARS ACTIVITIES, THE FOLLOWING TECHNOLOGY AREAS REQUIRED DURING 1992-1995 AS A BRIDGE TO SUCH ACTIVITIES
- SYSTEMS ENGINEERING PROCESSES FOR ROBOT INTEGRATION
- MAN/MACHINE COOPERATIVE CONTROL
- 3-D REAL-TIME PERCEPTION
- MULTIPLE-ARM REDUNDANCY CONTROL
- MULTI-AGENT REASONING AND VERIFICATION*
- MANIPULATOR CONTROL FROM MOVEABLE BASE
- MECHANISMS
- SENSORS

* ALSO APPLIES TO AUTOMATION

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

RECOMMENDATIONS/ISSUES (Cont'd)

- MANY TECHNOLOGIES IN THE ROBOTICS DISCIPLINE ARE LEVERAGED WITH OTHER SUPPORT. THE FUNDING SCENARIOS DEVELOPED HEREIN ARE BASED ON CONTINUED EQUIVALENT OF GREATER SUPPORT IN THOSE NON-OAST FUNDED PROGRAMS.
- THE RESULTS OF THIS SESSION SHOULD BE WEIGHED AGAINST EXISTING PROGRAMS AND PRIORITIES PRIOR TO ADOPTION OF SPECIFIC TECHNOLOGY RECOMMENDATIONS.

MULTIPLE-ARM REDUNDANCY CONTROL:

- R&D HAS SHOWN THAT THIS TECHNOLOGY IS MATURE ENOUGH TO BE DEVELOPED FOR "MID-TERM" (1995--2000) SPACE ROBOTIC SYSTEMS.
- INCREASING DEGREES-OF-FREEDOM CAN BE ADDED (IF DESIRED AND NECESSARY) TO MEET MANIPULATION OBJECTIVES OTHER THAN END-EFFECTOR POSITIONING. AT LEAST SEVEN DOF ARE NEEDED FOR COLLISION AVOIDANCE WHILE IN CONTACT.
- COST OF ADDING EXTRA ARMS AND EXTRA DEGREES-OF-FREEDOM MUST BE TRADED OFF AGAINST ADDITIONAL CAPABILITY.

SENSORS:

- THIS AREA INCLUDES ALL THE MEANS, PASSIVE AND ACTIVE, BY WHICH THE HUMAN TELEOPERATOR, OR (LATER) THE SEMI-AUTONOMOUS ROBOT COLLECTS INFORMATION ABOUT THE ENVIRONMENT.
- ADVANCES IN SENSORS ARE REQUIRED TO IMPROVE THE CAPABILITIES FOR SAFE AND EFFECTIVE TELEROBOTIC OPERATION IN THE SPACE STATION ENVIRONMENT.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

RECOMMENDATIONS/ISSUES (Cont'd)

SENSORS:

- SENSOR TECHNOLOGIES INCLUDE:
- MACHINE VISION, INCORPORATING SUCH AREAS AS VARIABLE RESOLUTION AND ZOOM; STEREO VISION, SCANNERS, INTEGRATED LIGHTING CONTROL, AND INFRARED DETECTORS
- DATA BASE OF ROBOT ACTIVITIES AND TASKS
- LASERS AND OTHER RANGING DEVICES FOR USE IN PROXIMITY OPERATIONS, GRAPPLING, AND WORKSPACE OPERATIONS
- SPECIALIZED SENSORS FOR EXTERNAL ROBOTS INCLUDING LEAK DETECTORS, INTEGRATION, ULTRASONIC, OR OTHER NDT INSPECTION SENSORS TO SUPPORT THE DIAGNOSIS OF MALFUNCTIONING EQUIPMENT OR OTHER TASKS
- FORCE/TORQUE SENSORS AND CONTACT SENSORS
- SENSORS FOR POTENTIAL IVA ROBOTS INCLUDING ATMOSPHERIC SAMPLERS AND AUDIO SENSORS
- THE ROBOTIC SYSTEMS MUST INTERACT WITH PHYSICAL OBJECTS IN ITS ENVIRONMENT. IT MUST BE ABLE TO NAVIGATE FROM A KNOWN POSITION TO A NEW LOCATION WHILE AVOIDING ANY CONTACT WITH OBJECTS ENROUTE. TO ACCOMPLISH THIS, COLLISION AVOIDANCE AND NAVIGATION TECHNOLOGY REQUIRE DEVELOPMENT. THEREFORE, SENSORS ARE REQUIRED WHICH ARE ABLE TO ACQUIRE HIGH-RESOLUTION DATA DESCRIBING THE ROBOT'S PHYSICAL SURROUNDINGS WHILE FUNCTIONING WITHIN COMPUTATIONAL RESOURCES OF THE SYSTEM.

TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ISSUES RAISED IN PLENARY SESSION (R. KOHRS, 1/16/90)

ISSUE:

- THERE EXISTS A NEED FOR USEFUL, HARD REQUIREMENTS FOR FTS AND MSC AND A NEED TO ASSIGN JOBS TO EACH (THERE ARE NO SPECIFIC REQUIREMENTS IN CURRENT DOCUMENTATION).

RESPONSE:

- A TASK IS UNDERWAY ENTITLED "EXTERNAL MAINTENCE AUDIT" TO ALLOCATE TASKS BETWEEN ROBOTICS AND EVA. TASK MANAGERS ARE C. PRICE AND W. FISHER.

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ISSUE:

- THERE EXISTS A NEED FOR COMMONALITY AMONG HAND CONTROLLERS; THERE ARE CURRENTLY SIX TYPES.

RESPONSE:

- AN INFORMAL TASK (i.e. NO ALLOCATED FUNDS) IS UNDERWAY BETWEEN BEN BARKER (SE&I LEVEL II) AND DEAN JENSEN, (JSC MANNED SYSTEMS) ENTITLED "JOINT LEVEL 2 - JSC STUDY: HAND CONTROLLER COMMONALITY PROCESS." THE OBJECTIVE OF THE TASK IS "TO RECOMMEND THE NUMBER AND TYPE OF HAND CONTROLLER CONFIGURATIONS THAT CAN MEET SPACE STATION REQUIREMENTS."
- A TASK, CONDUCTED BY W. HANKINS, IS UNDERWAY AT LaRC TO EVALUATE 4 TYPES OF HAND CONTROLLERS WITH AND WITHOUT FORCE-FEEDBACK.

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