NASA's SPACE PLATFORM TECHNOLOGY PROGRAM AND PLANNING

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SUMMARY

As part of the Civil Space Technology Initiative, NASA has established a space platform technology program which encompasses two ongoing programs as well as active planning for new platform initiatives in such areas as advanced heat rejection technologies, advanced space suits, advanced life support, and better support equipment (refrigerators, furnaces, etc.). Platform technology is extremely important because it provides both the basis for future missions and enhanced national competitiveness in space.

INTRODUCTION

The space platform is the foundation of any space mission whether manned or unmanned. The space platform encompasses essentially everything outside the payload, including (as appropriate) structure, power, propulsion, thermal management, life support, space suits, and guidance, navigation, and control. The space platform has to be light weight to minimize the launch weight (and the launch cost), but it must be strong enough to withstand launch loads. The space platform has to maintain its attitude and orbit in a stable manner. The space platform serves in a sense as a utility by supplying, for example, power and, in some cases, life support to the payloads and crew (ref. 1). In many ways, space platform technology is generic in that the technology can be applied to many different kinds of missions. For example, a light-weight solar array technology could be applied to Space Station *Freedom* (S.S. *Freedom*), commercial satellites, space science missions, or human exploration of the Moon and Mars. Thus, investment in space platform technology can benefit the U.S. space program across the board.

OBJECTIVES

NASA's Office of Advanced Concepts and Technology (OACT) has a space technology program composed of two principal elements: Base Research and Technology (R&T) program and the focused Civil Space Technology Initiative (CSTI). Within the CSTI program, OACT has established a Space Platforms Technology program to develop the technologies to increase on-orbit mission efficiency and decrease life cycle costs for future manned and unmanned science, exploration, and commercial missions (ref. 1). Within NASA the space platforms program is primarily designed to respond to the identified needs of NASA's space science program and NASA's S.S. *Freedom* program; however, there is a strong focus on developing technologies of use to the broader U.S. space community, both government and commercial. Additional objectives include:

- Developing technologies that will decrease launch weight and increase the efficiency of space platform functional capabilities
- Developing technologies that will increase human productivity and safety of manned missions
- Developing technologies that will increase maintainability and reduce logistics resupply of long-duration missions
- Identifying and developing flight experiments in all technology and thrust areas that will benefit from the utilization of S.S. *Freedom* facilities.

The "vision" of the Space Platform Technology Program includes:

- World leadership in space platform technology
- Development to enable better, lower cost missions
- Improving the American competitive position.

The Space Platform Technology Program currently has two funded elements: controls-structures integration (CSI) and a ground test of a 2-kilowatt (kW) solar dynamic (SD) power system. Looking 10 years into the future, the specific objectives of the Space Platform Technology Program include:

- Developing solar dynamic receiver units with specific powers of 25 W/kg and a 50-percent mass reduction
- Developing technology to support high-performance integrated control/structure systems design

as well as these objectives for planned programs:

- Developing advanced heat rejection technologies to accommodate growth S.S. *Freedom*
- Developing an advanced, light-weight concentrator array with twice the efficiency of existing arrays
- Developing advanced batteries with a performance of 60 W-h/kg and a design life greater than or equal to 5 years
- Developing advanced extravehicular mobility unit (EMU) technologies to support an increase in demand for S.S. *Freedom* extravehicular activity (EVA) operations while reducing cost and ensuring health and safety

- Upgrading the S.S. *Freedom* environmental control and life support system (ECLSS) to reduce logistics requirements, increase crew safety, and to match projected increases in crew size in the post 2000 period

- Developing reliable user support systems (such as refrigerators and furnaces) to enable the conduct of experiments on S.S. *Freedom*

- Developing advanced deep-space power management and distribution (PMAD) components to reduce the mass by a factor of 2, the parts count by 75 percent, and to increase the low-voltage power conservation efficiency to greater than 90 percent

- Reducing radioisotope power source fuel requirements by increasing thermal-to-electric conversion efficiency by up to 3 times.

BACKGROUND

Contributions of Base R&T to Space Platforms

NASA-sponsored R&T has already contributed to the improvement of space platforms. Some recent examples include (refs. 1, 2, and 3):

- Nickel-hydrogen battery technology—Improved specific energy lifetime (including for low-Earth orbit (LEO) applications) which will benefit S.S. *Freedom* and which provided support to the decision to change to nickel-hydrogen batteries for the Hubble space telescope (HST).

- NASCAP (NASA Charging Analysis Program) spacecraft charging model—This model has been used to modify the design of the S.S. *Freedom* electrical system to overcome potential electrical arcing and sputtering problems.

- Long Duration Exposure Facility (LDEF)—This experiment has provided a wealth of data on space environmental effects (as amply demonstrated by these proceedings and earlier proceedings).

- Life support technologies—Regenerative technologies for water recovery and recycling for crew consumption and for recovery of oxygen for crew consumption have been developed. Thermal control system technology has also been developed. Models and chemical sensors are being developed.

- Multipropellant resistojets—This propulsion technology offers improved performance over standard chemical propulsion systems for attitude control and maneuvering, and it can run on waste water from the life support system on S.S. *Freedom.*

- Large area solar cells—Early work has led to the use of large area solar cells (maximized active area) on S.S. *Freedom.*

- Arcjet thruster—Low-power arcjet technology has been taken to the point where it is now being baselined on commercial satellites (e.g., Telstar IV) to improve station keeping while reducing propellant mass.

Technology Trends

Figure 1 illustrates the breakout of the deployment mass of S.S. *Freedom*. This represents a "fixed" mass, but the resupply mass breakout shown in Figure 1 illustrates the benefits to be achieved by reducing the resupply (in such areas as spares, ECLSS, propulsion, and crew support) and, hence, the cost of maintaining S.S. *Freedom*. Figure 2 illustrates the S.S. *Freedom* resupply needs and the technologies which could reduce the resupply. Eventually over the lifetime of S.S. *Freedom*, the equivalent of several space shuttle launches could be saved with improved technologies. NASA's Office of Space Systems Development (OSSD), which is responsible for the overall management of the S.S. *Freedom* program, has identified many of these space platform technologies to OACT as being of high priority to the S.S. *Freedom* program.

Figure 3 shows the trends in launch masses for 195 robotic NASA spacecraft, indicating some recent upward movement. Figure 4 shows a typical mass breakout for today's robotic spacecraft. Currently, NASA is emphasizing smaller, cheaper, and quicker missions. The goals are to reduce the total launched mass to under 1,000 kg and to increase the payload fraction (ideally to 0.5). As shown in Figure 5, platform technologies such as power, propulsion, thermal management, structure, and guidance, navigation, and control (GN&C) can play critical roles in achieving these goals. Many of these space platform technologies have been identified as high priority to OACT by NASA's Office of Space Science and Applications (OSSA), which is responsible for the robotic science missions. In several cases there is an overlap between OSSA and OSSD technology development requests which indicates the generic nature of space platform technology.

OVERVIEW OF THE CURRENT SPACE PLATFORM TECHNOLOGY PROGRAM

Fiscal Year 1993 Program

Working within overall budget guidance, the Fiscal Year (FY) 1993 Space Platform Technology Program consists of only two ongoing elements: (1) power and thermal management (specifically a 2-kWe solar dynamic power system ground test) and (2) structures and dynamics (specifically the CSI program). These two programs are discussed in the following two sections.

Solar Dynamic Test Program

Growth in S.S. *Freedom* will be limited by available power. While the baseline S.S. *Freedom* design will use photovoltaic (PV) planar arrays (~14 percent efficient), such arrays are not feasible for meeting the power requirements anticipated for S.S. *Freedom* evolution because of their high atmospheric drag characteristics and the associated mass penalties related to reboost and propellant resupply. One option to increase the power of S.S. *Freedom* while minimizing mass and drag area is to

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use the more efficient solar dynamic power system technology. In the past, concerns have been expressed over the long-term performance of rotating machinery and thermal energy storage (TES) systems. The solar dynamic power system program will address many of these concerns by ground testing, in a space vacuum chamber with a solar simulator, the essential components of a solar dynamic power system. (A related flight experiment will address the thawing and freezing of TES material in a microgravity environment.) The testing and analysis will be conducted to support scaling the models up to at least 20 kWe. In FY 1992, the SD program, which is being managed by Lewis Research Center (LeRC), awarded a contract to design, fabricate, and test a 2-kWe solar dynamic space power system. In addition, the program completed the system requirements review for the 2-kWe solar dynamic space power system. In FY 1993, the program will complete the preliminary design review and the critical design review. In addition, the refurbishment of the government-furnished equipment (turbine-alternator-compressor and the recuperator) will be completed, and fabrication of the new hardware will be initiated. More information can be found in Reference 4.

Controls-Structures Integration Program

CSI brings together, in a unified manner, the control and structural aspects of space platforms to reduce spacecraft dynamic response and to improve the control and pointing capabilities of spacecraft. Out of the CSI program will come unified controls-structures modeling, analysis, and design methods which will allow a complete iteration on all critical design variables in a single integrated computational framework. CSI will enable increased pointing precision; increased flight path control; increased use of articulated components; increased use of multipayload platforms with multiple interacting control systems; and (as needed) increased platform sizes and lower frequencies (ref. 1). One source of information on CSI may be found in the papers presented at the annual AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conferences.

The CSI program is being conducted at three NASA Centers (Jet Propulsion Laboratory (JPL); Langley Research Center (LaRC), and the Marshall Space Flight Center (MSFC)) in a coordinated effort involving space science technology, space platform technology, and the Base R&T program. In FY 1992, the CSI program completed the CSI benefits study for Upper Atmospheric Research Satellite (UARS) and Earth Observing System (EOS) class missions and identified an approach to decrease the jitter by a factor of 5. A NASA Research Announcement (NRA) was issued for the Phase III guest investigator program at five cooperating ground test facilities (JPL, LaRC, MSFC, Edwards Air Force Base, and Kirtland Air Force Base). The Class I integration design methodology was validated by means of a rebuilt (Phase I) evolutionary model. Tests run on the space shuttle remote manipulator system (RMS) using a LaRC-developed control algorithm have shown substantial improvements in instrument pointing jitter and reduction of the settling time.

In FY 1993, the CSI program will focus on:

- S.S. *Freedom*/Space Transportation System (STS) assembly simulations
- Phase I evolutionary ground testbed model ground test results
- Middeck Active Control Experiment (MACE) critical design review
- Follow-on shuttle engineering simulator testing of RMS active damping for payloads of large mass

- Initial control tests for multipayload pointing
- Structural system identification testing of Phase II CEM
- Integrated design of GOES-I spacecraft
- Integrated design methodology for Class-II-type mission
- Advanced control laws for Class II experimentally evaluated
- Modal testing of hybrid-scale erectable components, major subassemblies, and full assembly of MB-5 configuration.

The future focus of CSI will include:

- Space shuttle RMS
- S.S. *Freedom*
- Earth observing platforms
- "Flagship" missions.

Contribution and Relationship of Current Program

The two ongoing programs will contribute to the nation's space capabilities.

Solar Dynamic Power Program

The solar dynamic power program will provide proof-of-concept through ground testing. This information is directly relevant to the original S.S. *Freedom* solar dynamic power module design. The test hardware will be flight configured and, through analysis and testing, the results will be scalable to 20 kWe. Again, the importance relates to the reduced area and reduced mass compared to the existing S.S. *Freedom* PV/battery system. The solar dynamic ground test program builds on the ongoing solar dynamic component technology program being conducted in the Base R&T program.

CSI Program. The CSI program has already demonstrated the following benefits:

- An increase of 4× in the maximum antenna diameter for a large geostationary platform that meets pointing and jitter requirements
- A decrease of 5× in the amount of settling time for the shuttle RMS during S.S. *Freedom* assembly operations
- A decrease of 5× in the pointing jitter error for a multipayload spacecraft similar to UARS.

The CSI also benefits from and is related to ongoing CSI technology development in the Base R&T program.

SPACE PLATFORMS TECHNOLOGY PROGRAM STRATEGIC PLANNING

Planning Process

As part of the OACT Integrated Technology Plan (ITP), the user organizations (such as OSSD and OSSA) provided OACT in 1992 with a formal set of technology needs. Those related to space platforms are listed below:

Office of Space Systems Development

- Advanced heat rejection for growth S.S. *Freedom*
- ECLSS for S.S. *Freedom* (in particular closing the oxygen and water loops)
- High-efficiency space power (better batteries and solar cells)
- Advanced EMU (to reduce the resupply and refurbishment time)
- Orbital debris protection (to protect S.S. *Freedom*).

Office of Space Science and Applications

- Efficient/quiet/safe/reliable refrigerator for science experiments on S.S. *Freedom* or STS
- Improved GN&C for science spacecraft
- Improved electric power (in particular a small radioisotope thermoelectric generator)
- Improved CSI for antennas
- Long-life, light-weight batteries
- Better thermal control on spacecraft
- Improved EMU for S.S. *Freedom*
- Regenerative life support for S.S. *Freedom*
- Improved solar array/cell technology for science spacecraft
- Improved furnaces for materials experiments on S.S. *Freedom*.

In response to these needs, OACT established a Space Platform Technology Thrust Team managed by OACT and with members from Ames Research Center (ARC) (EMU), GSFC (thermal management), JPL (power, propulsion, GN&C), Johnson Space Center (JSC) (advanced EMU, refrigerator), LaRC (CSI, materials, nondestructive examination, environmental effects), MSFC (ECLSS), OSSA, OSSD, and the Office of Exploration (OEXP). The Thrust Team developed a series of initiatives to meet the user needs. These initiatives included goals, objectives, milestones, deliverables, and funding profiles. This information was forwarded to OACT management as part of the FY 1994 budget deliberations.

Figure 6 shows the platform planning approach, and Figure 7 relates the user needs to the space platform program. All elements (except furnaces) are covered in the plan. Figure 8 shows the road map to meet OSSD needs, and Figure 9 shows the road map to meet OSSA needs.

Science Platform Initiative

A very recent initiative in support of future OSSA missions is the small spacecraft initiative. Specifically, in FY 1993, OACT will be funding an advanced technology insertion program to reduce the mass, improve the performance, and reduce the schedule for the proposed Pluto Fast Flyby mission and the Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) mission. In addition, elements of the Base R&T program will be focused on technologies applicable in general to "microspacecraft" or "lightsats."

Future Directions in Platforms

In looking to the future, the Space Platform Technology Program will be focusing on:

- Commercial spacecraft (to enhance U.S. competitiveness)
- Changing Earth observing systems
- Microspacecraft for science missions
- Cooperative programs with industry and other agencies (such as electric propulsion technology for station keeping or orbital maneuvering).

SUMMARY AND OBSERVATIONS

Enhancing U.S. competitiveness in space and expanding scientific knowledge of Earth, the solar system, and the universe represents a tremendous technological challenge requiring a significant, long-term investment in space platform technologies. Space platform technology has the advantage of applying to a wide range of space systems and can benefit all types of users. Based on studies of existing platforms and estimating future costs for planned missions, it is clear that there is significant room for improvement. OACT has established a Space Platform Technology Program which, if implemented, will develop the necessary technologies to meet this challenge.

REFERENCES

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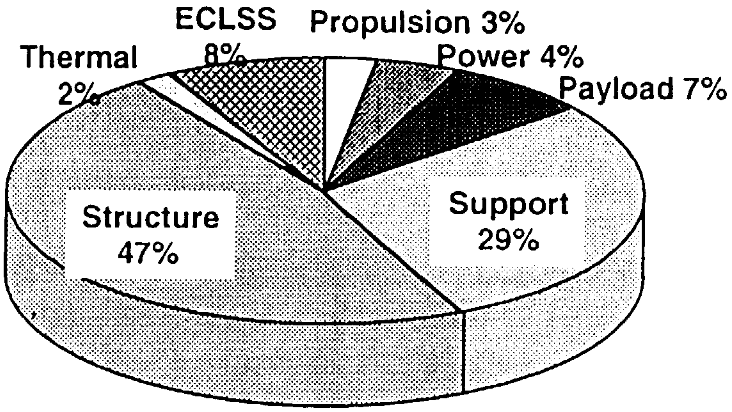
2. Bennett, G.L.: "The OAST Space Power Program." Space Photovoltaic Research and Technology–1989, proceedings of a conference held at NASA Lewis Research Center, Cleveland, OH, November 7–9, 1989, NASA Conference Publication 3107, 1991.

3. Bennett, G.L., Watkins, M.A., Byers, D.C., and Barnett, J.W.: "Enhancing Space Transportation: The NASA Program to Develop Electric Propulsion." NASA Technical Memorandum 4244, National Aeronautics and Space Administration, Washington, DC, October 1990.

4. Calogeras, J.E., and Dustin, M.O.: "The Ground Testing of a 2-kWe Solar Dynamic Space Power System." Proceedings of the 27th Intersociety Energy Conversion Engineering Conference, vol. 1, p. 1455, proceedings of a conference held in San Diego, CA, August 3–7, 1992.

Deployment

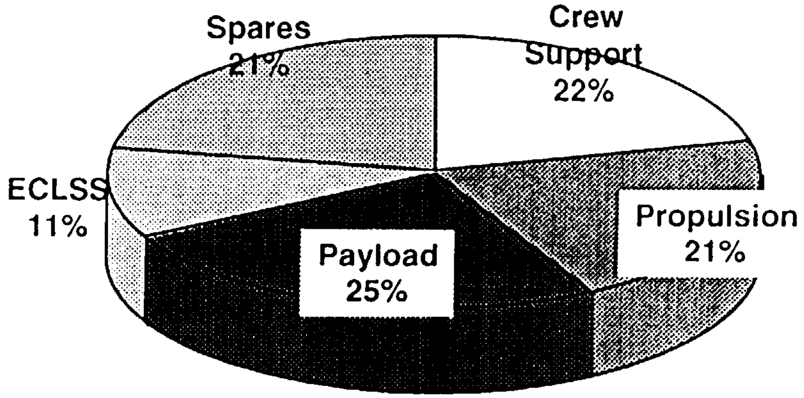
Total Launched Weight ≈ 189,000 Kg



Technology in Place for
Deployment
Configuration

Resupply

Total Weight ≈ 38,000 Kg/Year
Plus 36,000 Kg/year Carrier



Launch Cost ≈ $9,000/Kg

Technology Focus Shifting to Reducing Resupply Cost

Figure 1. Technology evolution of S.S. *Freedom*.

Specific Technologies Requested by NASA User Codes	Resupply Reduction
High Efficiency Space Power Systems (OSSD)	Spares/Propulsion
Thermal Control System (OSSA/OSSD)	Spares
Improved Solar Arrays/Cells/Batteries (OSSA)	Propulsion
Advanced Heat Rejection Devices (OSSA/OSSD)	Spares
Advanced Furnace Technology (OSSA)	Payload
Efficient, Quiet Refrigerator/Freezer (OSSA)	Payload
Advanced Extravehicular Mobility Unit Technologies (OSSA/OSSD)	Crew Support
Advanced Environmental Control & Life Support System (OSSA/OSSD)	ECLSS

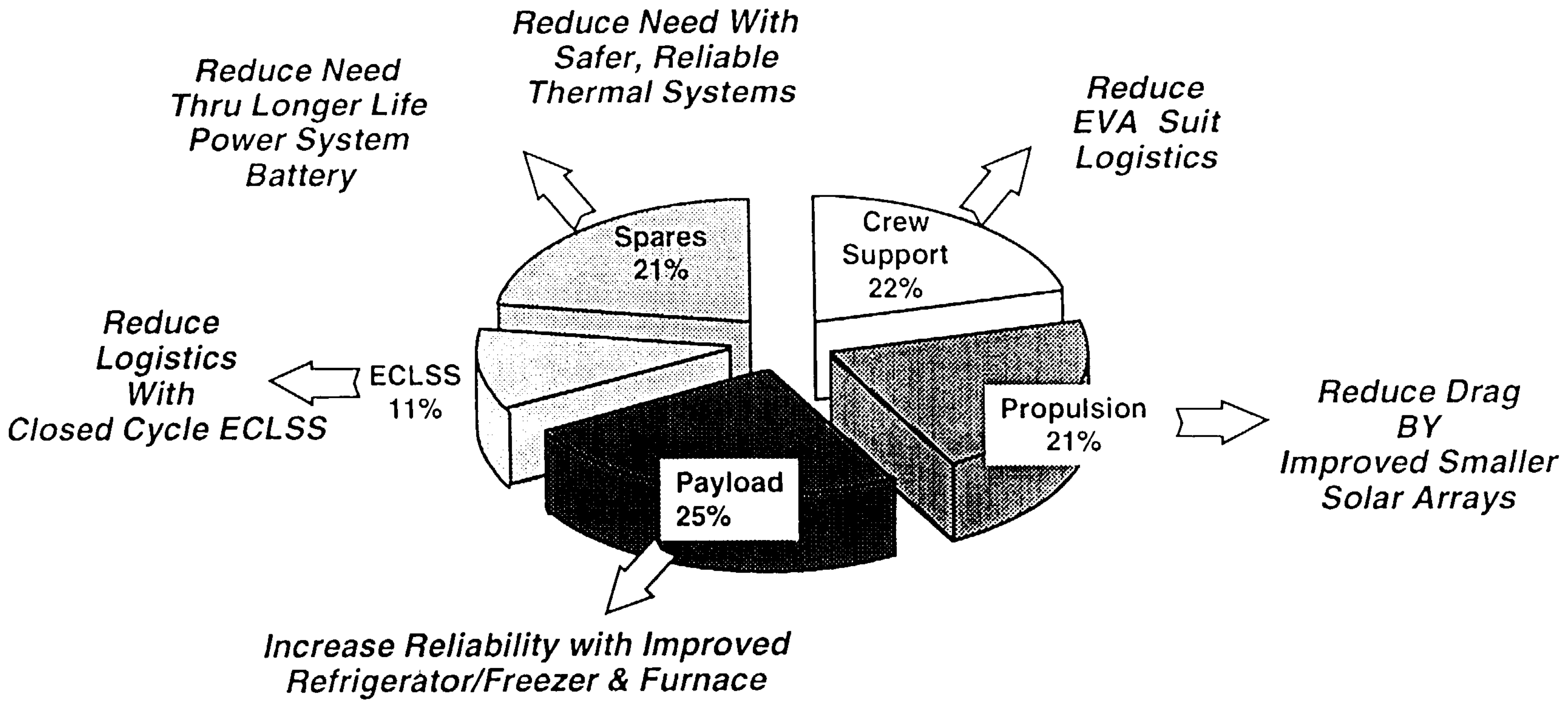


Figure 2. S.S. *Freedom* resupply needs.

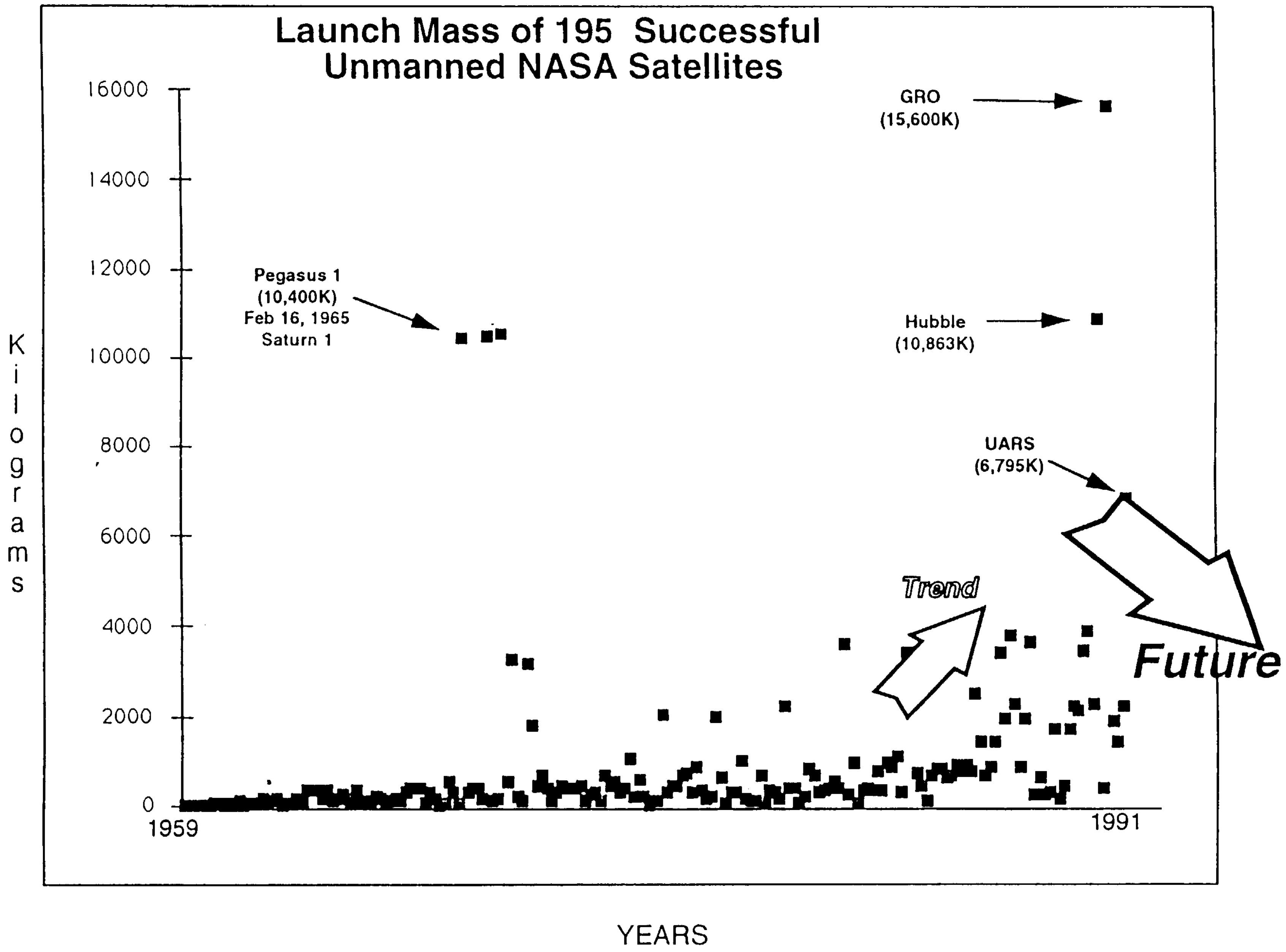
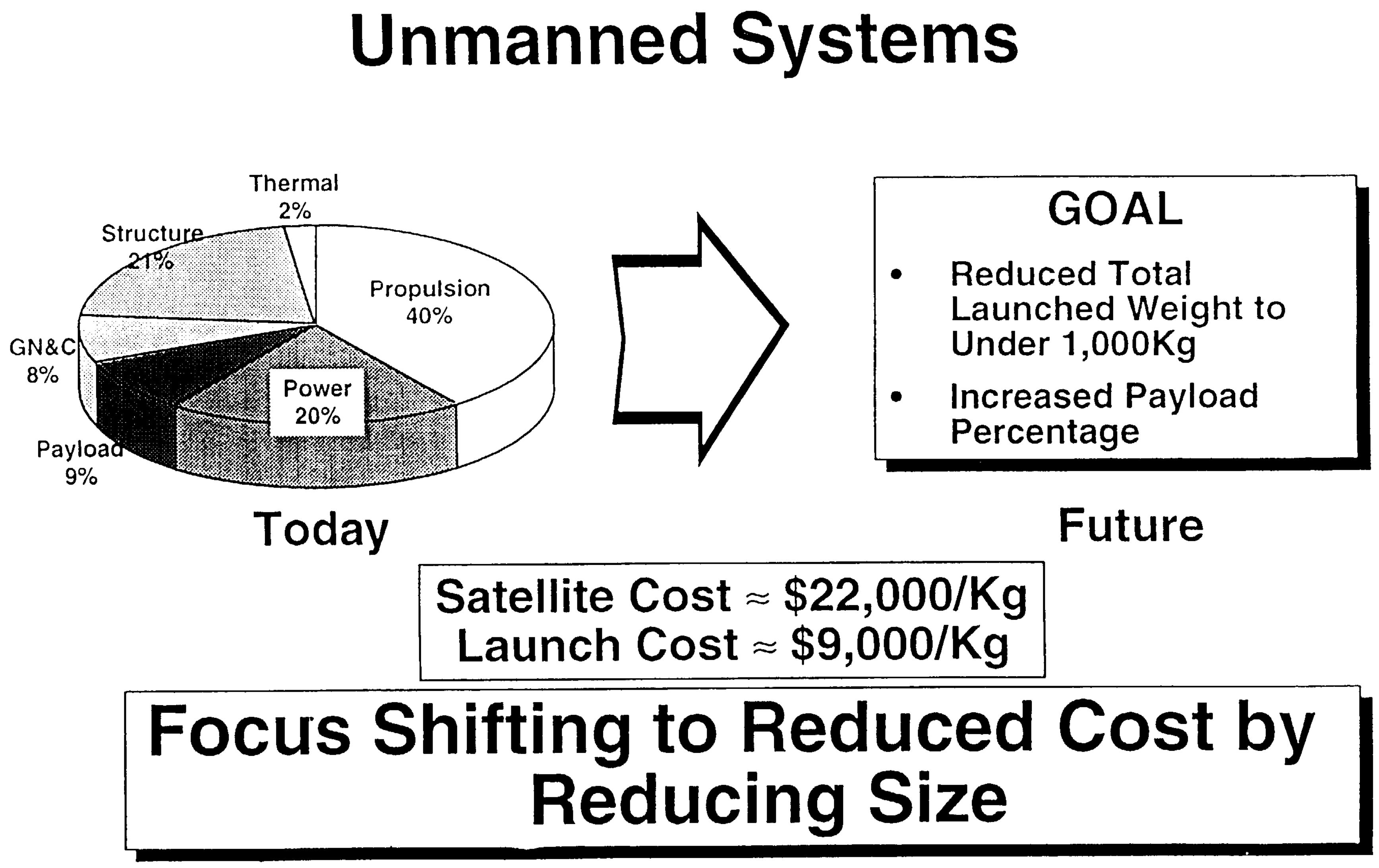


Figure 3. NASA unmanned missions.



Unnamed Systems

Today

GOAL

- Reduced Total Launched Weight to Under 1,000Kg
- Increased Payload Percentage

Future

Satellite Cost ≈ \$22,000/Kg
Launch Cost ≈ \$9,000/Kg

Focus Shifting to Reduced Cost by Reducing Size

Figure 4. Technology evolution of platforms.

Specific Technologies Requested by NASA User Codes	Cost Reduction
High Efficiency Space Power Systems (OSSA/OSSD)	Power System
Thermal Control System (OSSA/OSSD)	Thermal System
Improved Solar Arrays/Cells/Batteries (OSSA/OSSD)	Power System
Advanced Heat Rejection Devices (OSSA/OSSD)	Thermal System
Microsystems / Deep Space GN&C / Deep Space Power (OSSA)	All Systems
Controlled Structures/Large Antenna Structure/Area (OSSA)	Structure Systems

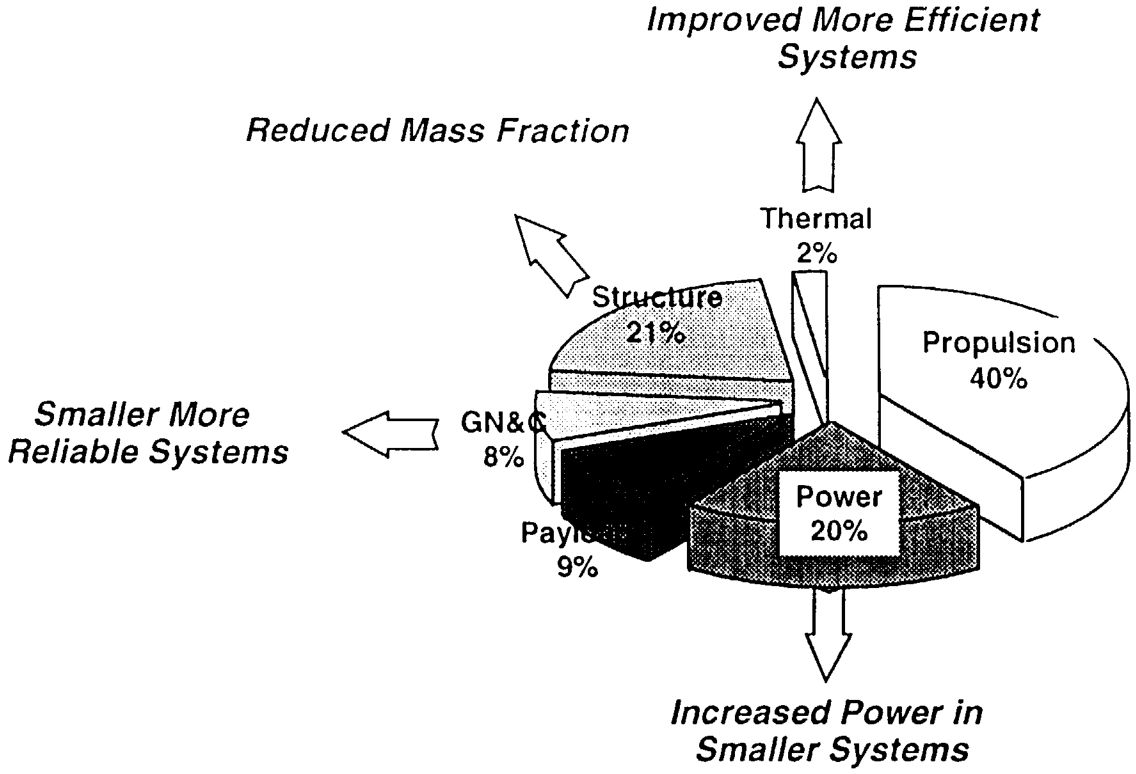
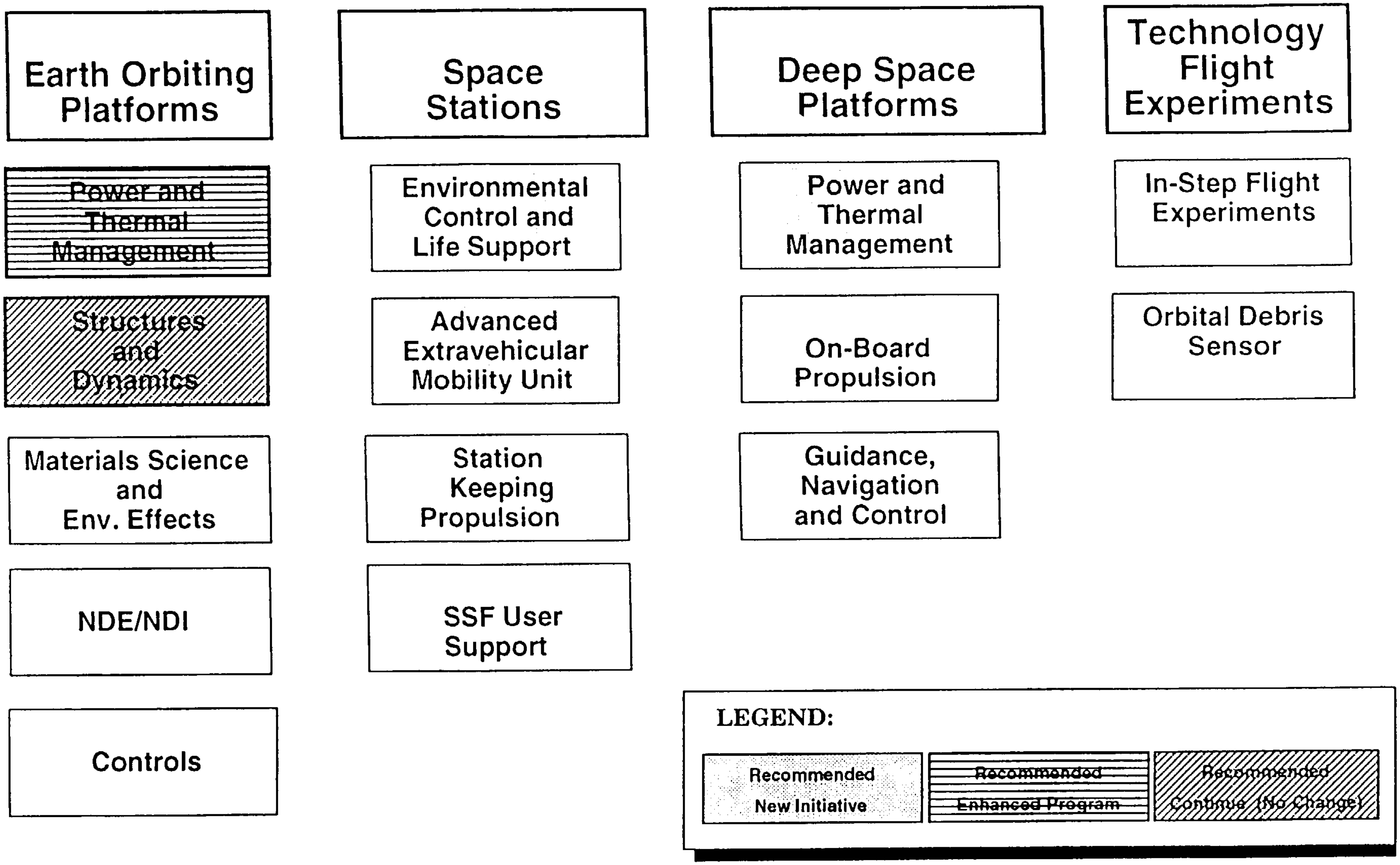


Figure 5. Science platform needs.



Earth Orbiting Platforms	Space Stations	Deep Space Platforms	Technology Flight Experiments
▤ Power and Thermal Management	Environmental Control and Life Support	Power and Thermal Management	In-Step Flight Experiments
▨ Structures and Dynamics	Advanced Extravehicular Mobility Unit	On-Board Propulsion	Orbital Debris Sensor
Materials Science and Env. Effects	Station Keeping Propulsion	Guidance, Navigation and Control	
NDE/NDI	SSF User Support		
Controls			

LEGEND:

- ░ Recommended New Initiative
- ▤ Recommended Enhanced Program
- ▨ Recommended Continue (No Change)

Figure 6. Platform thrust planning approach.

	USER NEED/PROGRAM AREAS	EARTH ORBITING PLATFORMS	SPACE STATIONS	DEEP-SPACE PLATFORMS
OSSD	ADVANCED HEAT REJECTION	PWR & THERM MGMT		
	ECLSS		ZERO-G LIFE SUPPORT	
	HIGH EFF. SPACE POWER	PWR & THERM MGMT		
	ADVANCED EMU		ZERO-G ADV EMU	
	ORBITAL DEBRIS PROTECTION			
OSSA	EFF/QUIET REFRIGERATOR		ADV REFRIG SYSTEM	
	GUIDANCE, NAV. & CONTROL			S/C GN&C
	ELECTRIC POWER (MINI-RTG)			PWR & THERM MGMT
	CONTROLLED STRUCT. INT.	▨ CSI PROGRAM		
	LONG-LIFE/LT.WT. BATTERIES	PWR & THERM MGMT		PWR & THERM MGMT
	THERMAL CONTROL			PWR & THERM MGMT
	IMPROVED EMU		ZERO-G ADV EMU	
	REGEN LIFE SUPPORT		ZERO-G LIFE SUPPORT	
	SOLAR ARRAY/CELLS	PWR & THERM MGMT		PWR & THERM MGMT
	FURNACES			

▨ FUNDED   PARTLY FUNDED   UNFUNDED

Figure 7. User needs/space platform matrix.

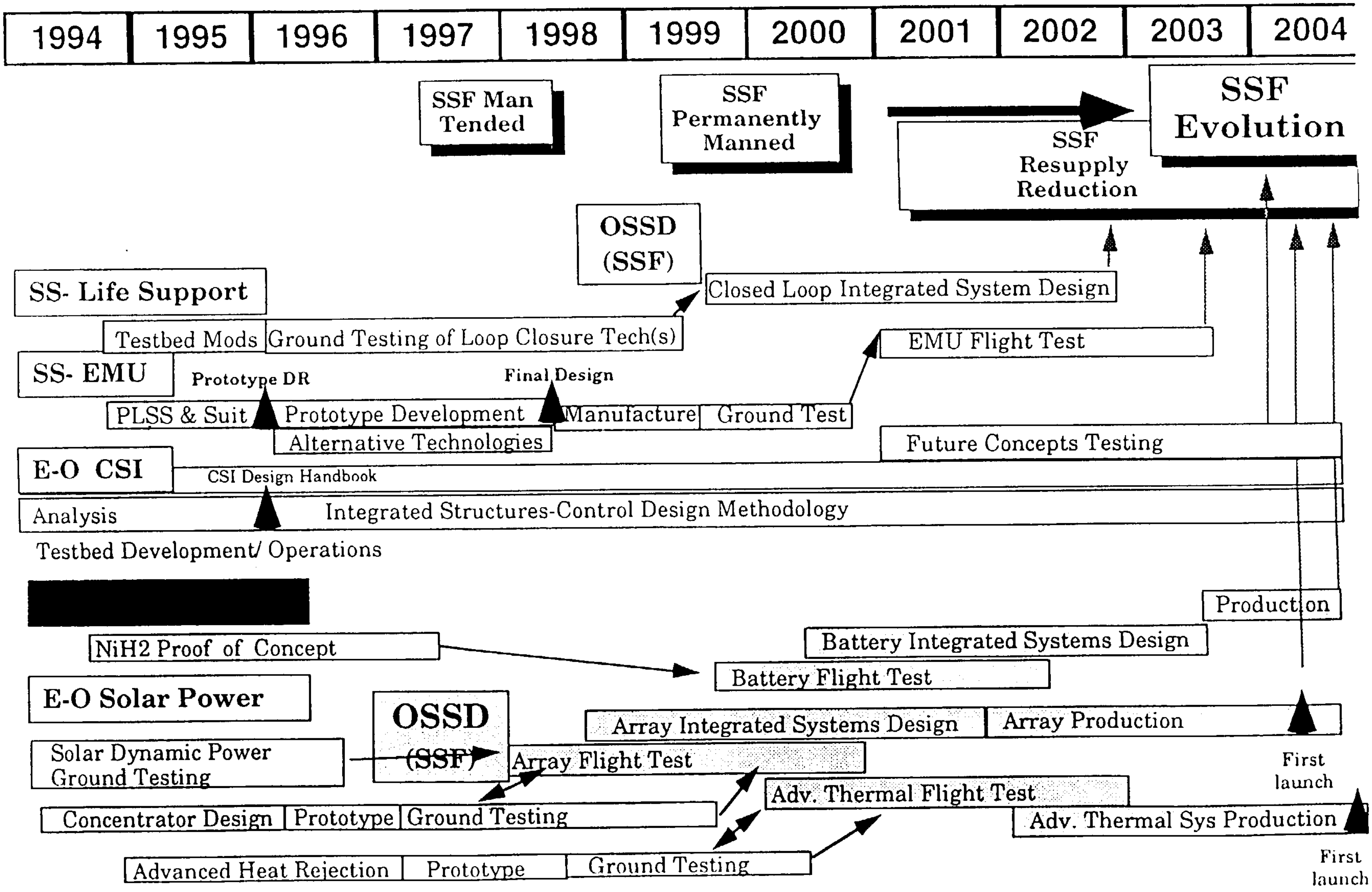


Figure 8. Road map to OSSD needs.

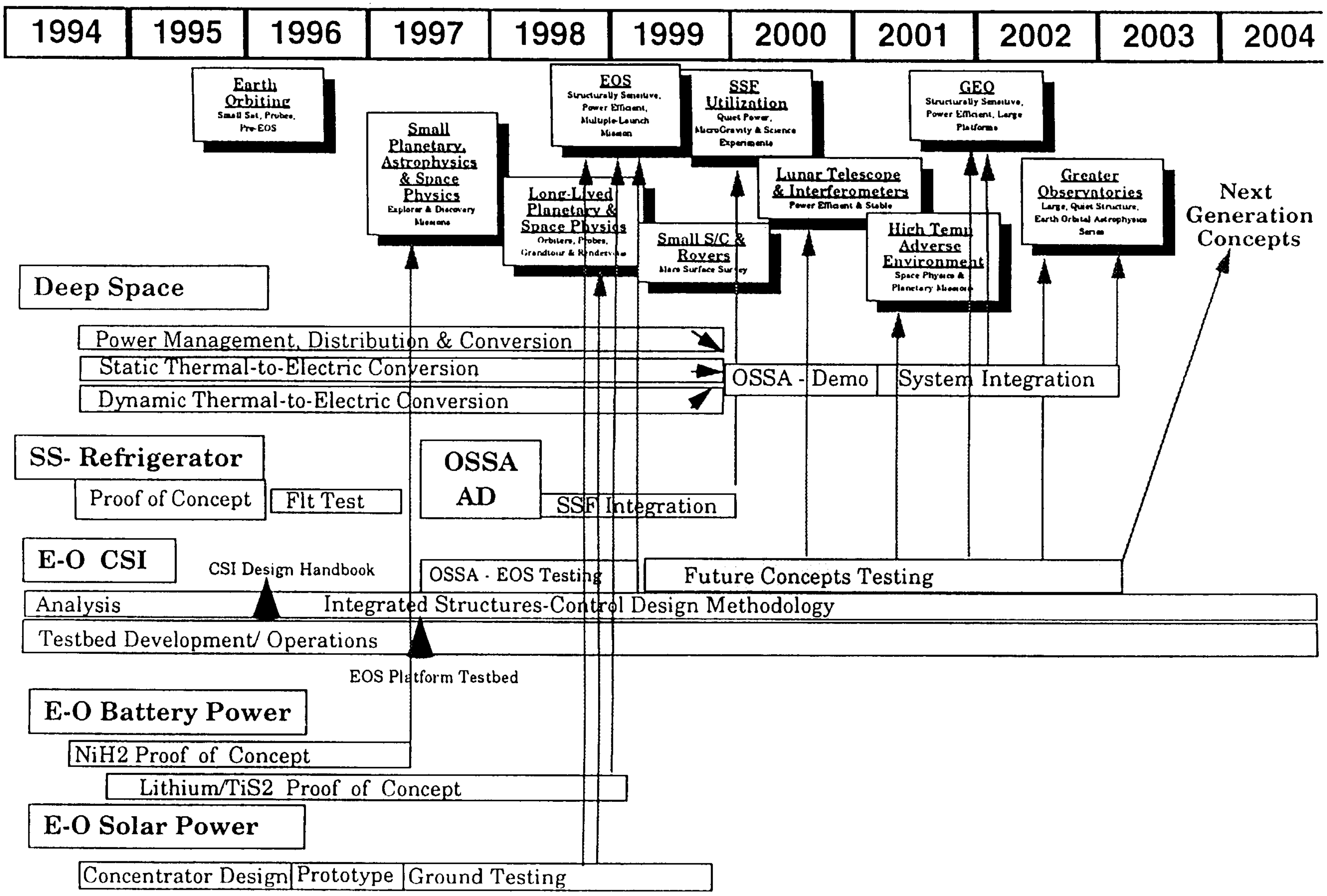


Figure 9. Road map to OSSA needs.