# The New Millennium Program Architecture and Access to Space

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*Abstract*—The New Millennium Program (NMP) validates technologies that will support future NASA earth and space science missions[1]. NMP flight validates as many subsystem- and system-level technologies as funding permits. If the program can be designed, or architected, around the use of cost-effective Access-To-Space (ATS) accommodations, NMP's cost for access to space will be reduced and more technologies can be flown.

Examples of alternate ATS accommodations are: less-expensive spacecraft and launch vehicles, space platforms other than free-flying spacecraft, synergies with other projects, partnering with unrelated missions, and back-to-basics networking with colleagues through conferences and other venues.

Stepping into the world of alternative ATS accommodations and 'ridesharing' also crosses paths with a variety of individual technologists and small mission developers with essentially similar challenges as the NMP. The scope of validation or experiment may be different, but the principles and lessons learned are the same.

The ATS trade space is broader in scope than the more typical project's choice of which spacecraft and launch vehicle are required for its mission. The particular challenge for NMP is to anticipate and plan for future ATS approaches while not knowing which technology will fly (due to the competitive nature of the program). With so many variables in this scenario, the problem quickly becomes complex. However, the use of programmatic constraints and a systematic look at the trade space provides a reference upon which those decisions can be based.

This paper identifies the trade space but focuses on two alternate approaches: using less-expensive spacecraft and partnering with other missions. Less-expensive spacecraft can provide a platform for flying NMP subsystem technologies, and partnering with other missions can be a cost-effective approach for NMP system-level technology validations.

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## 1. INTRODUCTION

The goal of the NMP [1] is to flight validate technologies that enable future NASA earth and space science missions. The selection of the technology to be flown is competition-based, a process initiated by the release of a NASA Research Announcement (NRA). The NRA establishes the technology areas, defines the Technology Readiness Levels [2] and desired capabilities, and provides guidelines for programmatic cost and schedule constraints. The competitive process is similar to the NASA AO process, which competes various science missions (ESSP, MIDEX, Discovery, New Frontiers).

NMP NRA technology competitions alternate between subsystem and system validations. NMP provides the architecture for each NRA as it applies to ATS, i.e., how the technology will be accommodated in space including both spacecraft/platform and launch vehicle services. For subsystem technologies, a spacecraft or carrier/platform will be required. For system-level technology validations, the spacecraft is often tailored to unique requirements, e.g., solar sails or aerocapture. Both subsystem and system validations require a launch to space.

As the planning begins for each NRA, an assessment is made on how the NRA should be programmatically structured: what ATS accommodations will be provided by NMP versus the proposer, and the total funding for the overall mission.

The challenge here is planning a mission without knowing the mission particulars! The design of an end-to-end space mission is theoretically well-known (ref). There is nothing mysterious here. But NMP is challenged by using variable ATS assumptions. Compounding the problem is an unknown payload set, due to the nature of the competition. Stated another way, the problem is to design a mission with variable ATS approaches (usually these are fixed) and with an unknown, variable payload set.

Insight into the potential payload set is part of the solution. A systematic analysis of the options is another part of the solution. This paper presents the rationale for considering the alternative ATS approaches in the first place, and introduces the alternatives. After discussing the ATS trade space, an example alternative for NMP subsystem validations is discussed, as well as an example for NMP systems validations.

## 2. The Rationale for Seeking Alternative ATS Accommodations—Cost Trades for Access to Space.

Before the NRA is released NMP will consider potential options for the structuring of the project, especially the ATS options. The overriding funding driver is the cost of the spacecraft and launch vehicle. Figure 1 illustrates that any savings in spacecraft or launch cost will significantly reduce the cost per project, enabling NMP to spend more money on technology and less on access to space. The five sample mission costs used in Figure 1 [3] are early pre-Phase A (full cost accounting) mission estimates, defined per a typical Jet Propulsion Laboratory mission work breakdown structure (WBS). While the individual missions vary in absolute dollar value, the overall pattern is clear: spacecraft and launch vehicle are the drivers for mission cost.

Figure 1 also points out that zeroing in on launch vehicle costs alone provides significant funding leverage for alternative ATS approaches. For example, $30 M can go a long way toward building an adaptor fitting to 'fly along' with another mission or paying for additional rocket strap-ons for a mass-shy mission (that would welcome a more capable rocket). Both of these approaches would lead to a less-costly NMP technology validation mission.

## 3. Alternative ATS Accommodations

So what are these alternative ATS accommodations? The word 'alternative' refers to options that go beyond the fundamentals of most space missions—the basic assessment of a spacecraft and launch vehicle that is optimum for a given mission. Technology missions have an advantage over science missions because their mission design is more flexible—perhaps the pointing control requirements (a cost

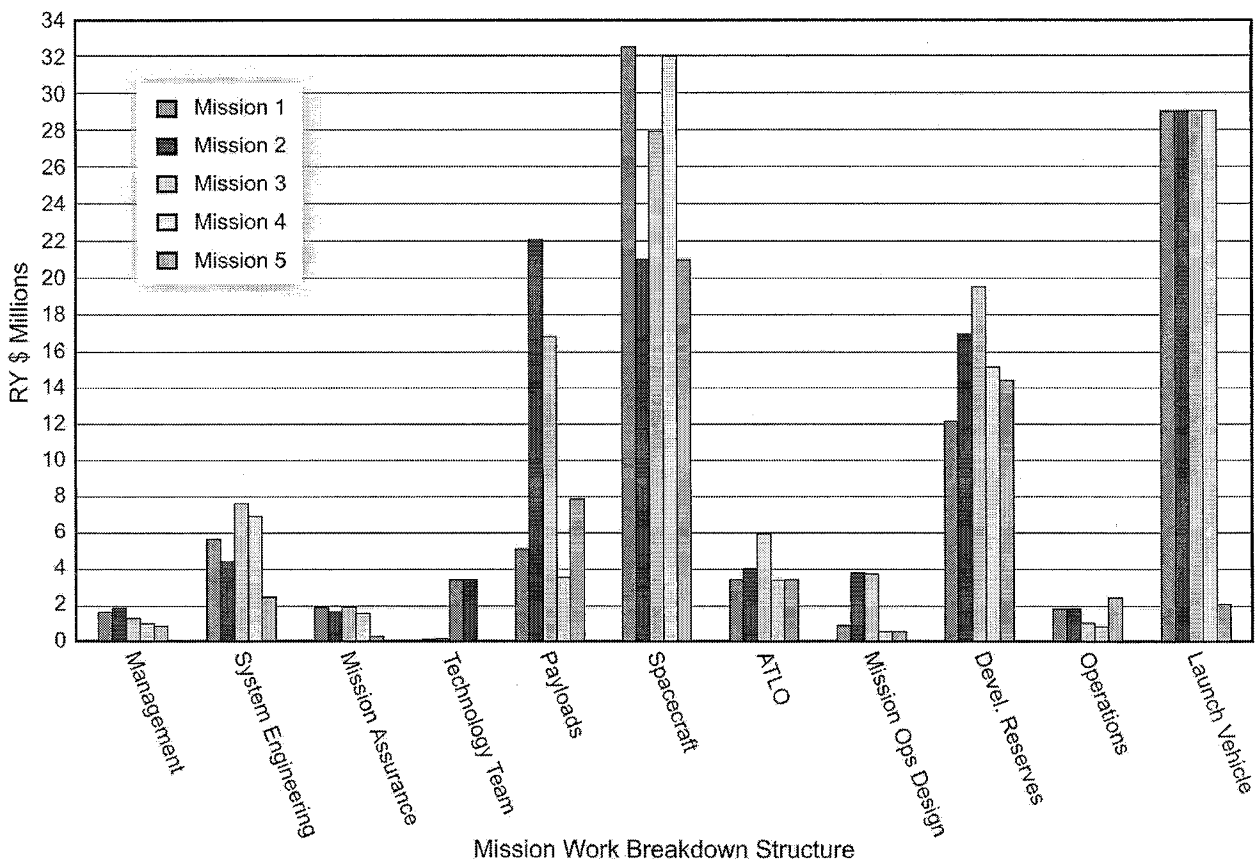


**Figure 1.** Full-cost accounting WBS of five sample missions, showing dominant spacecraft and launch vehicle costs

driver) can be relaxed, or the orbit may not require a high performance (and high cost) launch vehicle.

Table 1 summarizes these alternatives, noting the value/relevance for both NMP subsystem and system technology validation missions.

The first alternative, less expensive spacecraft, is perhaps self-evident as a cost savings, but the NMP dilemma is understanding what capabilities will be needed for future missions. The more capable a spacecraft needed, the more cost involved. NMP has addressed this in 2 ways. First, a study was funded to invite spacecraft builders to propose an inexpensive class of spacecraft that could accommodate the Space Technology 6 (ST6) [4] subsystems that were in Phase A competition at that time. Secondly, NMP has just completed a second round of subsystem technologies (ST8) [5] and, with the passage of time, is assembling a knowledge base of various flight needs (The next section of this paper goes into this in more detail.)

For Table 1's second alternative, less-expensive launch vehicles, time is a factor that prohibits immediate use of this obvious choice—inexpensive launch vehicles are teasingly close to reality, but are not yet available.

The next four alternatives in Table 1 involve the interaction of NMP with other programs: as a payload on other platforms, and partnering with other missions. The categorization of related and unrelated missions is a conscious delineation—there is much more flexibility in finding matches with missions if technology is not required to be related to the partner mission.

The importance of the last alternative, networking, cannot be over-emphasized. It is the most important element of these alternative approaches. Without a broad understanding of the status of each of the other elements in Table 1, these alternatives cannot be taken advantage of.

## 4. ALTERNATE FOR SUBSYSTEM MISSIONS: LESS-EXPENSIVE SPACECRAFT

NMP ST6 was the first technology validation mission to address subsystems (prior ST missions were system-level only). Eight subsystem technology areas were identified in the NRA[2], provided that the ATS options would either fly on an NMP-provided spacecraft (known as the New Millennium Carrier, NMC), or would propose an alternative ATS accommodation. The idea here was to not limit the ATS options and allow the proposer to suggest alternatives to the NMC as well.

Anticipating the possibility of a NMC, NMP released an RFP seeking a low-cost (~\$15 M) solution for a spacecraft. The low cost would be feasible given the reduction in robustness that is typical for a science spacecraft. There was also an anticipation of aerospace industry growth, enabling a reduction in the cost of some spacecraft hardware, although it is not clear that this has happened. The study results were

**Table 1**. Alternative ATS approaches are potential cost savings for the dominant WBS elements in Fig. 1, spacecraft and launch vehicle

| Alternative | Rationale/example | Feasibility for NMP Subsystem validation | Feasibility for NMP System validation |
|---|---|---|---|
| **Less expensive spacecraft** | NMP NMC carrier study, NASA RSDO catalogue provide insight into cost/capability trades | A set of unrelated technologies are flown on a single spacecraft | Tailoring spacecraft capability to a system mission often precludes using a 'cheap' spacecraft |
| **Less expensive launch vehicles** | Pegaus, FALCON1, Scorpius, ESPA on EELV | Only Pegasus is flight-qualified at this time (2004) | Only Pegasus is flight-qualified at this time (2004) |
| **Other platforms** | ISS, X37, Shuttle | Current flight restrictions prohibit Shuttle or ISS use, but these options are especially useful for deployable and heavy (mass) technologies | Often not relevant because of fixed Shuttle or ISS orbits |
| **Related missions** | Science mission will gain credibility from the technology and supports the development | Feasible if the accommodation is planned well in advance | Feasible especially if the technology is planned as a precursor to the science mission |
| **Unrelated missions** | Mission has excess capability (or needs more capability), benefits from an NMP funding partner | Requires planning well in advance, but decoupling 'relevance to mission' yields many more opportunities | Requires planning well in advance, but decoupling 'relevance to mission' yields many more opportunities |
| **Networking** | NRO-NASA Rideshare Conference, U.S. Air Force Space Test Program | Requires NMP to serve as a broker for the unrelated | Negotiations often done by the NRA proposers |

somewhat successful at attaining a low-cost spacecraft, but the more important issue proved to be defining potential payloads for this less-expensive spacecraft.

Anyone familiar with payload accommodation knows that it involves a technical matching of payload requirements and spacecraft capability, with a large number of parameters to be assessed. Furthermore, the higher the spacecraft capability, the higher the spacecraft cost. To reduce some of these unknowns and focus on NMP needs, ST6 technology types were used as the test case for the NMC study. There were 25 to 30 payload requirements that provided insight into the accommodation needs of each technology. For simplicity, Table 2 presents only a sample set.

The specifics of the technology are left off Table 2 to make a point. Scanning these requirements, the reader can see that the mass ranges from <1 kg to as much as 560 kg. Volume also varies significantly, as do power and telemetry rates. Since these fundamental payload requirements vary so much, by necessity the solution to accommodating the subsystems must take into account more than one approach to ATS. In turn, the accommodation requirements will drive the characterization and organization of different 'solution sets'. While technology is certainly the focus of the NMP, the ATS accommodation assessment can view the technologies simply as a set of 'black boxes'[3]. As long as the flight requirements are understood, the technology type is irrelevant—the spacecraft and the mission 'solution sets' must be able to accommodate the interface requirements in Table 2.

The reader is again reminded that the goal here is to anticipate what ATS accommodation is feasible for future NMP NRAs, without knowing a priori what the technology set will be. With the approach described here, the ST6 subsystems served (and continue to serve) as a measure of the feasibility of future subsystem accommodation concepts.

## 5. ALTERNATE FOR SYSTEM MISSIONS: PARTNERING WITH OTHER MISSIONS

It is not commonly done, but occasionally a partnering is established between different NASA space flight missions. NMP's EO1, for instance, was co-manifested with SAC-C and launched on a Delta II. The cost savings can be large, or enable the use of a higher-performance (higher cost) launch vehicle. The advantages and disadvantages have to be weighed on a case-by-case basis.

What gets really challenging is trying to match missions when the NMP technology mission is not finalized. This apparent mismatch occurs because the programmatic partnering by necessity should occur in the early phases of

**Table 2.** A trade space of 'black box' (first column) payload interface requirements can be generalized for a variety of subsystem technologies, creating a framework for assessing ATS options.

| | Total mass, kg | Ave. power, W | Dimensions, L x W x H, cm | Tlm rate, bps | Data storage, MB | Pointing, mr 1-sigma | Radiation environ. | Orbit requirements |
|---|---|---|---|---|---|---|---|---|
| N | 4 and <1 | 25 | 15x13x11, 16 cm sphere | 2x10^6 | ~400 | Knowledge: 0.60 Accuracy: ~8 Stability: 2.5 | N/A | LEO 250-km to ~400-km circular |
| N+1 | 60 | >125 from array, 40 instruments | 0.75x10^6 (stowed vol.) 0.5x10^6 (deployed vol.) | 60 plus video | 12 plus video | Knowledge: 4.36 Accuracy: 34.91 Stability: 1.00 | N/A | Any |
| N+2 | 30 | 50 | 0.75x10^6 (stowed vol.) 0.5x10^6 (deployed vol.) | 8x10^6 | 2x10^6 | Knowledge: 0.10 Accuracy: 0.14 Stability: 0.05 | N/A | LEO |
| N+3 | 560 | 400 | 310x350x270 | 8x10^6 | 2x10^6 | Knowledge: 1.75 Accuracy: 17.50 Stability:TBD | N/A | 500 km @28 degrees |
| N+4 | 2 | 1.5 | 18x18x18 | 28,800 | N/A | Knowledge: <17.5 Accuracy: <17.5 Stability: <17.5 | N/A | LEO |
| N+5 | 430 | 85 | 115x115x225; 70x50x30 for electronics | 1200 | N/A | N/A | N/A | Standard STS orbit |
| | | | | | | | High rad | |

projects. But for NMP, the early phase (Phase A) is still under competition; a set of proposers are funded through Phase A. Again part of the solution is to create some 'black box' mission profiles, and then seek matches with other projects or programs. The potential partnership mission needs to be able to accommodate a range of NMP mission requirements, rather than a single point design. Working with the NMP competing teams, the mission requirements can be gathered, similar to the example of spacecraft interfaces in the section above, and a mission trade space can be established. The trade space would be designed to ensure that each competing team's needs would be met. Although this approach is more involved than finding a single match, the rewards are great for the additional effort required of the NMP.

Through the networking alternative identified in Table 1, a mission was identified as having excess mass capability due to the re-design of the mission. As it turns out, the partnering opportunity was lost due to schedule incompatibility, but the approach is described here to identify the systematic approach that can be applied.

Considering each mission as a 'black box' again, the mission parameters are gathered from the NMP teams in Phase A. The various parameters involved in orbital mechanics and mission design quickly become complex with too many variables and too many unknowns. The approach for the partnering assessment instead stretched the boundaries, and asked the question "Can the excess launch vehicle capability reach these orbits?" See Table 3.

NMP boundaries provided a generalized trade space that easily encompasses the needs of future NMP system-level missions. The question was whether or not these generous boundaries could be met with the excess launch capability. Of the three cases, Case A and Case B were confirmed as feasible. Case C could be met, but at a lower altitude.

**Table 3**. A trade space is defined which generously bounds the NMP system mission needs.

| Case | Mass, kg | Orbit |
|---|---|---|
| A | 300 | 36,000 km; any perigree; any inclination |
| B | 500 | >1500 km circular; any inclination |
| C | 300 | 20,000 km circular; any inclination |

## 6. Summary and Conclusion

The cost savings is why we care about seeking alternative ATS options for the NMP (Fig. 1). The NMP challenge is to design a mission without first knowing the payloads to be flown. This dilemma is overcome by first knowing the alternatives (Table 1), then identifying the trade space within which the mission must work for payload black boxes (Table 2), and for a range of flight options (Table 3). With this information in hand, an informed decision can be made and stability brought to the early planning of these competed technology missions.

Guiding principles for these alternative ATS approaches include: on-going networking to recognize potential partnerships; funding of feasibility studies; early planning (including exit strategies); and the ability to fund the accommodation impacts with partners (integration costs, launch vehicle adaptors, contributions or sharing of the launch vehicle costs, additional strap-on rockets, etc).

There is no question that these alternative partnering approaches bring added risk to both NMP and the potential partner. However, early alignment of the program/project schedules with well-defined, agreed-to milestones and having exit strategies prepared add enough stability that the risk can be managed and therefore should be considered. In some cases, the partnering can actually enable a (non-NMP) mission that otherwise could not quite attain the full mission that was desired.

A distinct advantage for NMP is its position as a program, rather than a project. As a program that manages a series of projects, NMP can anticipate future project needs and fund feasibility studies to ensure the technical and programmatic match with other projects or programs—this is financially difficult for individual projects already in formulation and development, but it is a cost-effective approach for NMP planning.

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## Biography

Linda Herrell has a BA in math/computer science/languages (1972, University of Texas) and a MSME in fluids and heat transfer (1983, City College of New York). Besides working as a computer science and thermal and structural analyst, she has worked as both a payload (instrument) and spacecraft systems engineer on Earth-orbiting (Hubble Space Telsecope, Earth Observing System (EOS)) and deep space (Cassini) NASA missions, and as Proposal Manager for several NASA science missions. She currently serves as the Program Architect for NASA's New Millennium Program.

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The particular challenge for NMP lies in taking advantage of these alternative approaches. Planning for future NMP projects requires an in-depth understanding of these options, and must also anticipate as-yet-undefined payloads (due to the competitive nature of the program)—with so many variables in this scenario, the problem quickly becomes complex. A more straightforward approach would be to ignore the alternatives and plan a business-as-usual mission. The benefits, however, are significant enough to warrant an assessment.

This paper introduces a trade space from which these options may be discussed. The advantages vary with the type of NMP mission (subsystem or system). This preliminary look at the option space focuses on two alternative approaches: using less-expensive spacecraft and partnering with other missions. Less-expensive spacecraft can provide a platform for flying NMP subsystem technologies, and partnering with other missions can be a cost-effective approach for NMP system-level technology validations.

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spacecraft is often tailored to unique requirements, e.g., solar sails or aerocapture. Both subsystem and system validations require a launch to space.

It is in this early planning stage that potential alternatives must be identified. The challenge here is planning a mission without knowing the mission particulars! The design of an end-to-end space mission is theoretically well-known [3]. There is nothing mysterious here. But NMP has the challenge of assessing variable ATS assumptions. Compounding the problem is an unknown payload set, due to the nature of the competition.

Stated another way, the problem is to design a mission with variable ATS approaches (usually these are fixed) and with an unknown, variable payload set. Part of the solution is found with insight into the potential payload set. Another part of the solution is a systematic analysis of the options.

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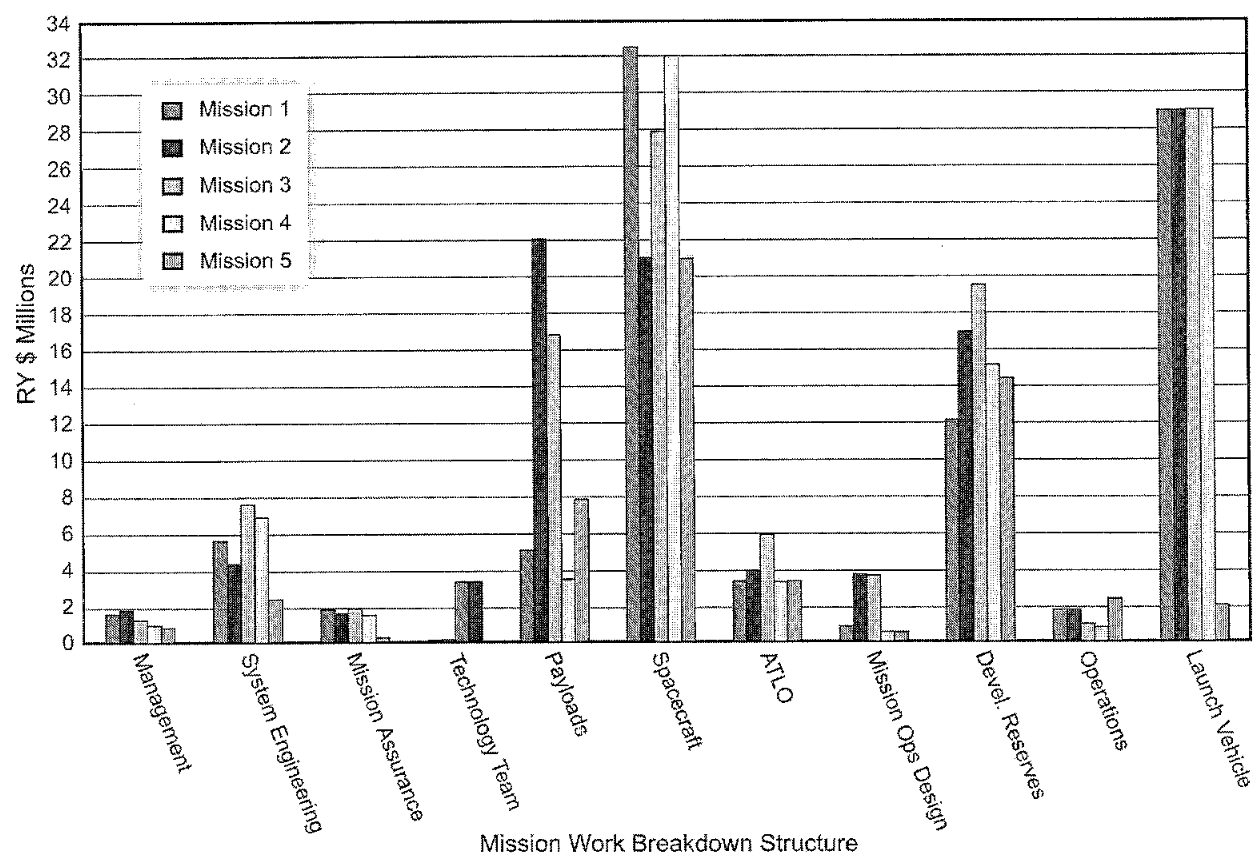


**Figure 1.** Full-cost accounting WBS of five sample missions, showing dominant spacecraft and launch vehicle costs

## 3. ALTERNATIVE ATS ACCOMMODATIONS

So what are these alternative ATS accommodations? The word 'alternative' refers to options that go beyond the fundamentals of most space missions—the basic assessment of a spacecraft and launch vehicle that is optimum for a given mission. Technology missions have an advantage over science missions because their mission design is more flexible—perhaps the pointing control requirements (a cost driver) can be relaxed, or the orbit may not require a high performance (and high cost) launch vehicle.

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The first alternative, less expensive spacecraft, is perhaps self-evident as a cost savings, but the NMP dilemma is to understand what capabilities will be needed for future missions. The more capable a spacecraft needed, the more cost involved. NMP has addressed this in two ways. First, a study was funded to invite spacecraft builders to propose an inexpensive class of spacecraft that could accommodate the Space Technology 6 (ST6) [5] subsystems that were in Phase A competition at that time. Secondly, NMP has just completed a second round of subsystem technologies (ST8) [6] and, with the passage of time, is assembling a knowledge base of various flight needs. (The next section of this paper goes into this in more detail).
For Table 1's second alternative, less-expensive launch vehicles, time is a factor that prohibits immediate use of this obvious choice—inexpensive launch vehicles are teasingly close to reality, but are not yet available.

The next four alternatives in Table 1 involve the interaction of NMP with other programs: as a payload on other platforms, and partnering with other missions. The categorization of related and unrelated missions is a conscious delineation—there is much more flexibility in finding matches with missions if technology is not required to be related to the partner mission.

The importance of the last alternative, networking, cannot be over-emphasized. It is the most important element of these alternative approaches. Without a broad understanding of the status of each of the other elements in Table 1, these alternatives cannot be taken advantage of.

**Table 1.** Alternative ATS approaches are potential cost savings for the dominant WBS elements in Fig. 1, spacecraft and launch vehicle

| Alternative | Rationale/example | Feasibility for NMP Subsystem validation | Feasibility for NMP System validation |
|---|---|---|---|
| **Less expensive spacecraft** | NMP NMC carrier study, NASA RSDO catalogue provide insight into cost/capability trades | A set of unrelated technologies are flown on a single spacecraft | Tailoring spacecraft capability to a system mission often precludes using a 'cheap' spacecraft |
| **Less expensive launch vehicles** | Pegasus, FALCON1, Scorpius, ESPA on EELV | Only Pegasus is flight-qualified at this time (2004) | Only Pegasus is flight-qualified at this time (2004) |
| **Other platforms** | ISS, X37, Shuttle | Current flight restrictions prohibit Shuttle or ISS use, but these options are especially useful for deployable and heavy (mass) technologies | Often not relevant because of fixed Shuttle or ISS orbits |
| **Related missions** | Science mission will gain credibility from the technology and supports the development | Feasible if the accommodation is planned well in advance | Feasible especially if the technology is planned as a precursor to the science mission |
| **Unrelated missions** | Mission has excess capability (or needs more capability), benefits from an NMP funding partner | Requires planning well in advance, but decoupling 'relevance to mission' yields many more opportunities | Requires planning well in advance, but decoupling 'relevance to mission' yields many more opportunities |
| **Networking** | NRO-NASA Rideshare Conference, U.S. Air Force Space Test Program | Requires NMP to serve as a broker to a set of unrelated subsystems | Negotiations often done by the NRA proposers (not NMP) |

## 4. ALTERNATIVE FOR SUBSYSTEM MISSIONS: LESS-EXPENSIVE SPACECRAFT

NMP ST6 was the first technology validation mission to address subsystems (prior ST missions were system-level only). Eight subsystem technology areas were identified in the NRA[2], provided that the ATS options would either fly on an NMP-provided spacecraft (known as the New Millennium Carrier, NMC), or would propose an alternative ATS accommodation. The idea here was to not limit the ATS options and allow the proposer to suggest alternatives to the NMC as well.

Anticipating the possibility of a NMC, NMP released an RFP seeking a low-cost (~$15 M) solution for a spacecraft. The low cost would be feasible given the reduction in robustness that is typical for a science spacecraft. There was also an anticipation of aerospace industry growth, enabling a reduction in the cost of some spacecraft hardware, although it is not clear that this has happened. The study results were somewhat successful at attaining a low-cost spacecraft, but the more important issue proved to be defining potential payloads for this less-expensive spacecraft.

Anyone familiar with payload accommodation knows that it involves a technical matching of payload requirements and spacecraft capability, with a large number of parameters to be assessed. Furthermore, the higher the spacecraft capability, the higher the spacecraft cost. To reduce some of these unknowns and focus on NMP needs, ST6 technology types were used as the test case for the NMC study. There were 25 to 30 payload requirements that provided insight into the accommodation needs of each technology. For simplicity, Table 2 presents only a sample set.

The specifics of the technology are left off Table 2 to make a point. Scanning these requirements, the reader can see that the mass ranges from <1 kg to as much as 560 kg. Volume also varies significantly, as do power and telemetry rates. Since these fundamental payload requirements vary so much, by necessity the solution to accommodating the subsystems must take into account more than one approach to ATS. In turn, the accommodation requirements will drive

**Table 2.** A trade space of 'black box' (first column) payload interface requirements can be generalized for a variety of subsystem technologies, creating a framework for assessing ATS options.

| | Total mass, kg | Ave. power, W | Dimensions, L x W x H, cm | Tlm rate, bps | Data storage, MB | Pointing, mr 1-sigma | Radiation environ. | Orbit requirements |
|---|---|---|---|---|---|---|---|---|
| N | 4 and <1 | 25 | 15x13x11, 16 cm sphere | 2x10^6 | ~400 | Knowledge: 0.60 Accuracy: ~8 Stability: 2.5 | N/A | LEO 250-km to ~400-km circular |
| N+1 | 60 | >125 from array, 40 instruments | 0.75x10^6 (stowed vol.) 0.5x10^6 (deployed vol.) | 60 plus video | 12 plus video | Knowledge: 4.36 Accuracy: 34.91 Stability: 1.00 | N/A | Any |
| N+2 | 30 | 50 | 0.75x10^6 (stowed vol.) 0.5x10^6 (deployed vol.) | 8x10^6 | 2x10^6 | Knowledge: 0.10 Accuracy: 0.14 Stability: 0.05 | N/A | LEO |
| N+3 | 560 | 400 | 310x350x270 | 8x10^6 | 2x10^6 | Knowledge: 1.75 Accuracy: 17.50 Stability:TBD | N/A | 500 km @28 degrees |
| N+4 | 2 | 1.5 | 18x18x18 | 28,800 | N/A | Knowledge: <17.5 Accuracy: <17.5 Stability: <17.5 | N/A | LEO |
| N+5 | 430 | 85 | 115x115x225; 70x50x30 for electronics | 1200 | N/A | N/A | N/A | Standard STS orbit |
| N+6 | 3 | 3 | 10x10x15 | 1 | 0 | N/A | High rad preferred | Any |

[2] ST6 was actually announced by an NMP Technology Announcement, and not by the current NRA process. For the purposes of this paper, however, they are essentially the same.

the characterization and organization of different 'solution sets'. While technology is certainly the focus of the NMP, the ATS accommodation assessment can view the technologies simply as a set of 'black boxes'[3]. As long as the flight requirements are understood, the technology type is irrelevant—the spacecraft and the mission 'solution sets' must be able to accommodate the interface requirements in Table 2.

The reader is again reminded that the goal here is to anticipate what ATS accommodation is feasible for future NMP NRAs, without knowing a priori what the technology set will be. With the approach described here, the ST6 subsystems served (and continue to serve) as a measure of the feasibility of future subsystem accommodation concepts.

## 5. ALTERNATIVE FOR SYSTEM MISSIONS: PARTNERING WITH OTHER MISSIONS

It is not commonly done, but occasionally a partnering is established between different NASA space flight missions. NMP's EO1, for instance, was co-manifested with SAC-C and launched on a Delta II. The cost savings can be large, or enable the use of a higher-performance (higher cost) launch vehicle. The advantages and disadvantages have to be weighed on a case-by-case basis.

What gets really challenging is trying to match missions when the NMP technology mission is not finalized. This apparent mismatch occurs because the programmatic partnering by necessity should occur in the early phases of projects. But for NMP, the early phase (Phase A) is still under competition; a set of proposers are funded through Phase A. Again part of the solution is to create some 'black box' mission profiles, and then seek matches with other projects or programs. The potential partnership mission needs to be able to accommodate a range of NMP mission requirements, rather than a single point design. Working with the NMP competing teams, the mission requirements can be gathered, similar to the example of spacecraft interfaces in the section above, and a mission trade space can be established. The trade space would be designed to ensure that each competing team's needs would be met. Although this approach is more involved than finding a single match, the rewards are great for the additional effort required of the NMP.

Through the networking alternative identified in Table 1, a mission was identified as having excess mass capability due to the re-design of the mission. As it turns out, the partnering opportunity was lost due to schedule incompatibility, but the approach is described here to identify the systematic approach that can be applied.

[3] For your information, the subsystems in Table 2 are, from the top: autonomous rendezvous sensor, solar concentrator array, optical communications, dual reflector telescope, low-power avionics, helium dilution cooler, and a serial bus.

Considering each mission as a 'black box' again, the mission parameters are gathered from the NMP teams in Phase A. The various parameters involved in orbital mechanics and mission design quickly become complex with too many variables and too many unknowns. The approach for the partnering assessment instead stretched the boundaries, and asked the question "Can the excess launch vehicle capability reach these orbits?" See Table 3.

NMP boundaries provided a generalized trade space that easily encompasses the needs of future NMP system-level missions. The question was whether or not these generous boundaries could be met with the excess launch capability. Of the three cases, Case A and Case B were confirmed as feasible. Case C could be met, but at a lower altitude.

**Table 3**. A trade space is defined which generously bounds the NMP system mission needs.

| Case | Mass, kg | Orbit |
|---|---|---|
| A | 300 | 36,000 km; any perigree; any inclination |
| B | 500 | >1500 km circular; any inclination |
| C | 300 | 20,000 km circular; any inclination |

## 6. SUMMARY AND CONCLUSION

The cost savings is why we care about seeking alternative ATS options for the NMP (Fig. 1). The NMP challenge is to design a mission without first knowing the payloads to be flown. This dilemma is overcome by first knowing the alternatives (Table 1), then identifying the trade space within which the mission must work for payload black boxes (Table 2), and for a range of flight options (Table 3). With this information in hand, an informed decision can be made and stability brought to the early planning of these competed technology missions.

Guiding principles for these alternative ATS approaches include: on-going networking to recognize potential partnerships; funding of feasibility studies; early planning (including exit strategies); and the ability to fund the accommodation impacts with partners (integration costs, launch vehicle adaptors, contributions or sharing of the launch vehicle costs, additional strap-on rockets, etc).

There is no question that these alternative partnering approaches bring added risk to both NMP and the potential partner. However, early alignment of the program/project schedules with well-defined, agreed-to milestones and having exit strategies prepared add enough stability that the risk can be managed and therefore should be considered. In some cases, the partnering can actually enable a (non-NMP) mission that otherwise could not quite attain the full mission that was desired.

A distinct advantage for NMP is its position as a program, rather than a project. As a program that manages a series of projects, NMP can anticipate future project needs and fund feasibility studies to ensure the technical and programmatic match with other projects or programs—this is financially difficult for individual projects already in formulation or early development, but it can be a cost-effective approach for NMP planning.

Finally it should be pointed out that this look into the world of alternative ATS approaches is a look into an ever-evolving environment. One need only have a successful development in the area of inexpensive launch vehicles, for example, to change the trade space and the conclusions.

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## BIOGRAPHY

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