

# A Pragmatic Access to Space Approach for the ST8 Mission

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*Abstract* — NASA's The New Millennium Program (NMP) approach to space flight validation of advanced technologies is to alternate between subsystem and system flight validations<sup>1</sup>. Candidates for each NMP project (subsystem or system) are competed through a NASA Research Announcement process, and proposal selection is determined by NASA Headquarters. Space Technology 8 (ST8) is the second NMP subsystem project. It will include technology experiments selected from four technology capability areas. The forecast for launch is 2008. The key distinguishing feature between the first subsystem project (ST6) and ST8 is the approach for access to space (ATS).

The ST6 Project was initiated in 1999—a time of great expectations for an expanded launch industry and potential for a great deal of 'ride-sharing' to space. Anticipating an environment rich with partnering possibilities, the ST6 competing teams sought and found a variety of accommodations for ATS (e.g., as payloads on other spacecraft, or as a payload on the shuttle's HitchHiker Program). Lessons learned from ST6 include the loss of partnerships or 'rideshares' in a time of decreasing launch availability, cancellation of a partner's project, and loss of the Space Shuttle (as of this writing) as a host platform.

The ST8 mission was initiated in 2003, after the 'crash' of the launch industry, and the NMP approach for access to space changed. NMP planned to provide a launch vehicle and carrier spacecraft that would accommodate the selection of subsystem technologies. Because of the competitive element of NMP, however, the technologies to be flown would not be known until a year after the start of the competition and that valuable time could be used to prepare for the spacecraft requirements, and align the spacecraft acquisition to coincide with the down-selection of the technology payload. NMP was confronted with a ('chicken-or-the-egg') dilemma: Since the technology payload has not been chosen, how do we scope the NMP carrier

requirements? If we wait to begin work on the spacecraft requirements until after NASA selects the technology payloads, we could lose a year or more toward enabling future space science missions. Part of the answer came from the competition itself. We knew the four categories of technologies and their needs, including an idea of what orbital conditions would be required (e.g., COTS computing radiation needed a 'radiation' orbit, and no team had any particularly difficult pointing requirements). Part of the answer came from prior studies funded by NMP with industry, which took a look at eight different technology-types and which combinations of types could be accommodated on a single spacecraft. And perhaps the most important part of the answer was to work with the competing teams from the beginning to iterate with them to understand their spacecraft/mission requirements.

This paper tells the story of the evolution of the access to space approach for the ST8 Project, with some insights and comments on the benefits and risks of this approach.

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## 1. INTRODUCTION

<sup>1</sup> 0-7803-8870-4/05/\$20.00 ©2005 IEEE

<sup>2</sup> IEEEAC paper #1428, 10 December 2004

In October 2003, the New Millennium Program (NMP) ST8 mission architecture challenge entered a crucial phase with the formal selection of 10 potential technology validation experiments in four technology areas. These four areas were:

- Deployment of Ultra Lightweight Booms,
- Deployment of Lightweight Solar Array,
- Thermal Management Subsystem for Small Spacecraft, and
- Commercial-Off-The-Shelf (COTS)-Based High Performance Computing for Space.

The ten proposed experiment concepts were funded to conduct a formulation (Phase A) study and provide a report describing a flight validation experiment in one of the four technology areas. The reports describe the nature of the technology advance being validated, the maturity level of the specific advance, an implementation plan for the experiment, and the cost and schedule estimated for implementation.

The NMP architecture challenge is to develop a mission concept before the payloads and their requirements have been defined.[1] Consequently, mission architecture and concept development must proceed in parallel with these payload formulation studies. As well, the architecture team must evaluate the feasibility of procuring a commercially available spacecraft bus to accommodate the set of experiments that will eventually be selected. This parallel process must also deal with the need to maintain separation between the competing study activities while developing a mission concept that is capable of satisfying as many subsets of the experiments as possible. In the final analysis, the mission concept and ATS must be compatible with the set of payload experiments that are selected by a competitive process and yet the selected experiment set is not known until well into the mission formulation process.

The approach to accomplishing this task revolves around several key issues:

1. Program guidelines for the mission specify a Pegasus XL launch vehicle and launch in FY'07-'08.
2. Identical mission concept data will be supplied from the architecture study to all payload studies.
3. The NMP will assign a technology specialist from each technology area be the formal interface between the payload studies and the mission architecture team.
4. Evolving mission concept material will be supplied to the payload study teams at an initial kickoff meeting and before the midterm of the payload formulation studies.

5. Each payload formulation study will supply the architecture team with initial estimates of mission/spacecraft requirements shortly after the kickoff, an update at the midterm progress reviews, and in the final payload experiment formulation study reports.

The experience of applying a process to accomplish this mission concept development and formulation task is the focus of this paper.

Figure 1 depicts the overall timeline flow of the mission development process.

## 2. PRIOR TO PAYLOAD FORMULATION STUDY SELECTION

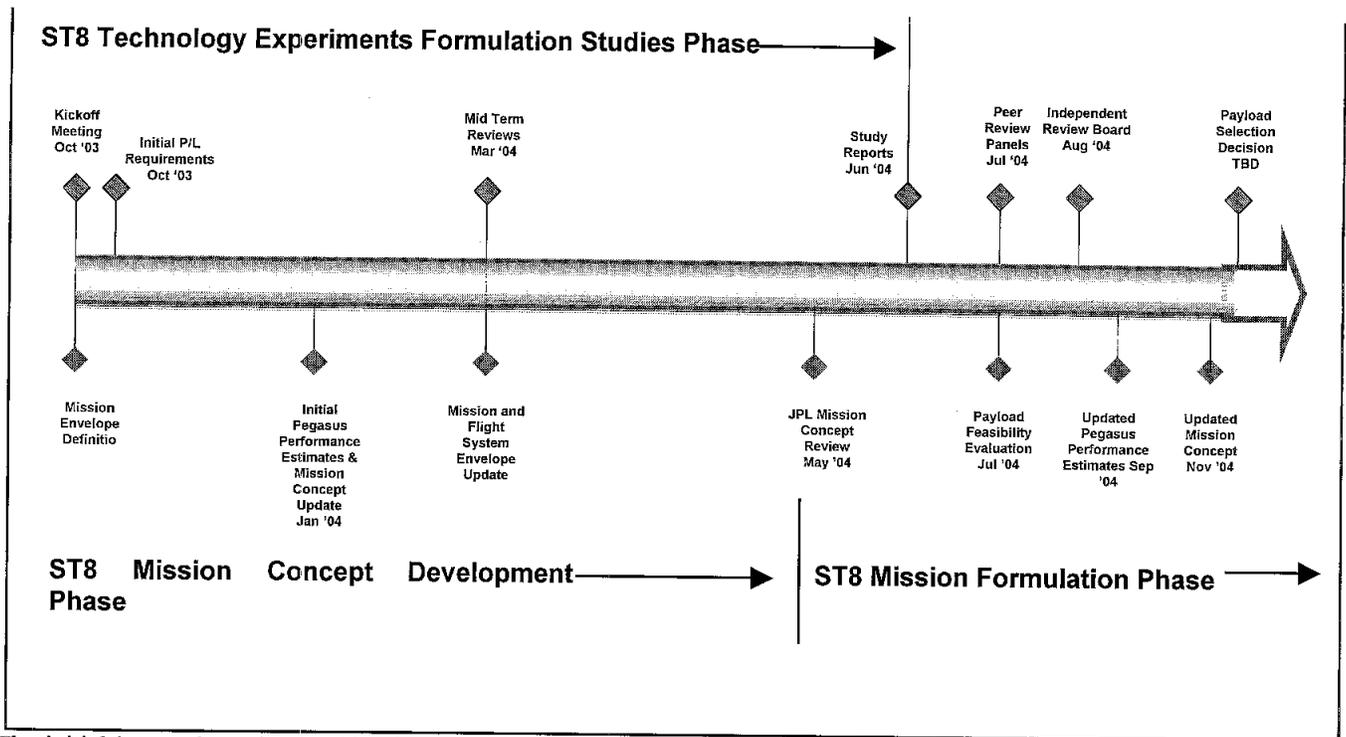
The overall guidelines for an NMP funded ATS approach had been defined earlier during the ST6 mission formulation period, based on use of a Pegasus class launch vehicle and a "Space Technology Carrier" (STC). These guidelines were passed to the payload studies in the NASA Research Announcement (NRA) [2] that defined the objectives to be achieved in each area and called for flight experiment proposals. A "technology carrier" in this context is a spacecraft bus whose payload is a set of technology validation experiments. This STC would be developed from a commercially available spacecraft bus design that would be compatible with the class of launch vehicle. The design of the STC would minimize cost and mission risk through use of existing technologies with flight heritage. The STC would only host the technology experiments which accomplish the NMP technology validation objectives.

Availability of valid STC candidates was assessed through funded concept studies of "New Millennium Space Technology Carriers". Industry participation in this study supplied a range of small, commercially available spacecraft bus designs that were credible solutions to hosting prospective technology validation flight experiments from the proposed set of ST6 payloads. Additional examples of potential commercial spacecraft designs came from the "catalogue" of the Goddard Spaceflight Center (GSFC) Rapid Spacecraft Development Office (RSDO). The RSDO catalogue represents a wide range of available spacecraft bus designs with flight

**Figure 1.** Summary mission development timeline

heritage, including several concepts overlapping STC study examples.

## 3. INITIAL STEPS –THE KICKOFF MEETING



The initial interaction with the 10 selected study teams was held on 7 October 2003. Guidelines for the study activities and products were presented along with the primary guidance on ATS and the process by which the ST8 mission architecture concept would be developed in parallel with the technology studies. The three most significant architectural inputs to the study participants were (1) the focus of ATS for ST8, (2) the process for interface between the studies and the mission concept development, and (3) a request for early identification of expected payload experiment characteristics.

The fundamental ATS guidelines included NMP's preferred use of the NMP funded STC on a Pegasus class launch vehicle. Other ATS approaches, including use of the International Space Station (ISS) and partnered hosts with NASA science missions or other host missions would have to be evaluated carefully during the experiment formulation studies to ensure that schedule and other programmatic variables were consistent with ST8 planning. An ATS approach provided by NMP is a stable, guaranteed project element that is under the control of the project management and the NMP Program Office and is less subject to cost and schedule impact from outside partners.

The process for interface between the mission concept development activity and the experiment formulation studies is driven by the need to "firewall" the competitive development of the experiment studies from each other while ensuring that all studies had access to the same level of mission concept information. Figure 2 illustrates the planned interaction between the parallel study activities.

The basic process allows for the architecture task to communicate with both the experiment studies and the outside launch services and radiation environment specialists on an as needed basis. In addition, there are

specific data deliverables to the architecture team from the experiment studies. Initial experiment requirement inputs are requested from the studies to allow development of a preliminary mission concept. A description of the resulting preliminary mission concept is to be supplied to the experiment studies and updated at the mid-term progress reviews. Increasingly detailed mission/carrier requirements will be furnished to the concept formulation process at the mid-term review and in the experiment final study reports. Figure 3 illustrates the data requested of the experiment teams at the kickoff to support the initial mission concept development.

#### 4. INITIAL MISSION CONCEPT

The initial mission concept was based on developing a "Carrier capabilities envelope" defined by the

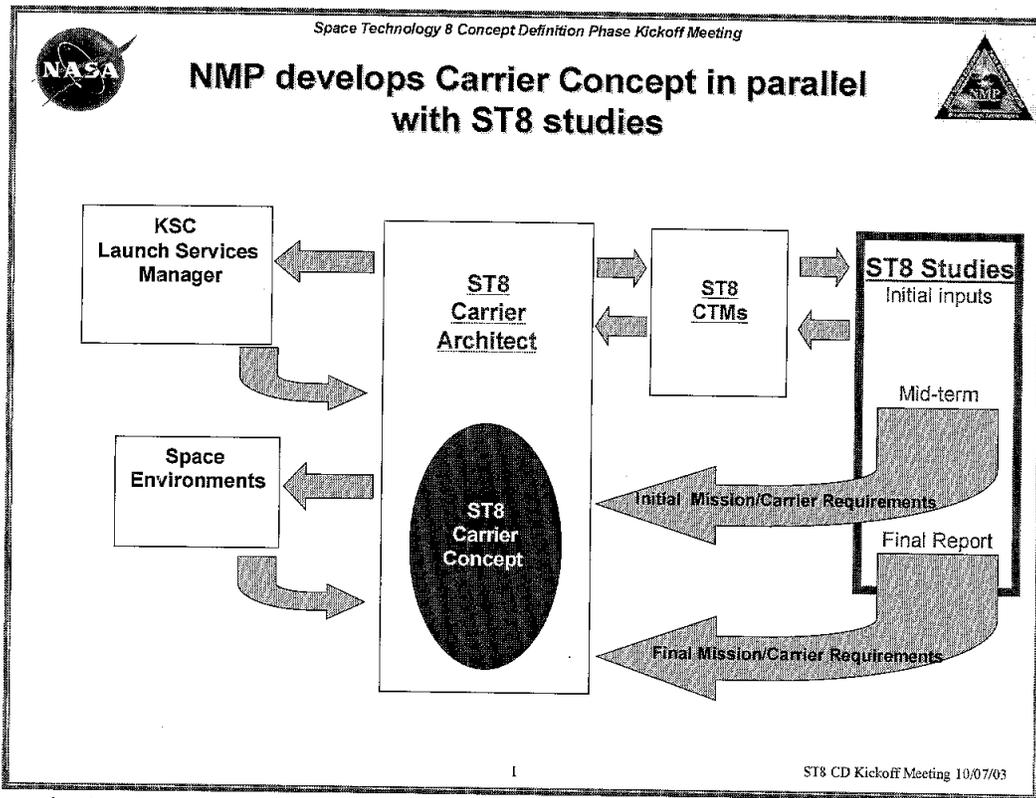


FIGURE 2 Organizational relationships in the study

Space Technology 8 Concept Definition Phase Kickoff Meeting

**Data requested from each team, ASAP**

- Initial rough estimates are needed to produce an early "envelope" of carrier performance

Experiment	NMC Host	Total	Peak	Dimensions	Data	Radiation	Orbit
	Status	Mass	Power	(l-w-h)	Storage		
	Carrier?	(kg)	(W)	(cm)	Tim rate (baud)	Pointing	s
COTS 1 - JPL	?	?	?	?	?	?	?
COTS 2 - Honeywell	?	?	?	?	?	?	?
COTS 3 - Boeing	?	?	?	?	?	?	?
Thermal 1 - Swales	?	?	?	?	?	?	?
Thermal 2 - GSFC	?	?	?	?	?	?	?
Boom 1 - ILC Dover	?	?	?	?	?	?	?
Solar Array 1 - ENTECH	?	?	?	?	?	?	?
Solar Array 2 - ABLE	?	?	?	?	?	?	?
Boom 2 - ABLE	?	?	?	?	?	?	?
Boom 3 - LMC	?	?	?	?	?	?	?

- More detail will be needed at the mid-term review and in the final report. See Section 3.5.6 (Access to Space) of the ST8 Study Guidelines.

1

ST8 CD Kickoff Meeting 10/07/03

FIGURE 3. Data requested from payload studies

projected mass injection capability of the Pegasus XL launch vehicle to a variety of orbits of potential interest. The COTS electronics payload concepts all required exposure to significant radiation environments in the nature of trapped protons in the lower Van Allen belts, the South Atlantic anomaly, and Galactic Cosmic Ray (GCR) flux. This was identified as the principal driver for a mission orbit configuration and suggested a launch from the Western Test Range to as near a polar orbit inclination as feasible. A maximum altitude of at least 1000 km was required to assure access to the radiation belts. The Pegasus mass performance capability suggests that an elliptical orbit is required to provide this altitude for a reasonable range of small spacecraft/payload masses. Freezing the line of apsides requires a low inclination on the order of 63.4 degrees, with a resulting loss in radiation exposure to GCR's.

A formal request for Pegasus performance estimates was made to the Kennedy Space Center (KSC) office managing the SELVS contract which procures Pegasus launch vehicles. The requested performance envelope was for estimates of the maximum achievable apogee for orbits with a 300 km perigee (injection) altitude, inclinations of 63.4 degrees and a range of 70 degrees to 90 degrees in five degree steps, for a range of injected flight system masses between 150 kg and 400 kg in 50 kg steps. The result of this study was reported in a set of tables which are summarized in the graph presented in Figure 4.

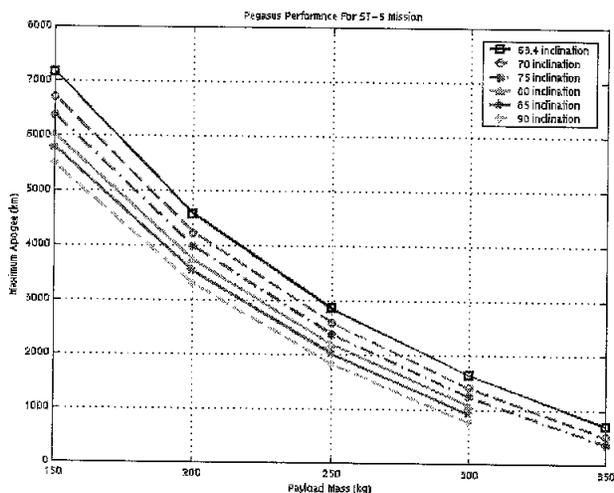


Figure 4. Apogee altitude as function of payload mass

Simultaneously, an assessment of the radiation environment in this range of orbits was accomplished. The COTS electronics technology lead arranged for a radiation environment specialist from the Aerospace Corporation to conduct the assessment and provide a report. The radiation flux for a variety of components was assessed, and it was noted that the highest fluxes of interest were in the 90 degree

inclination range, with a falloff of approximately 50% when the inclination was reduced to 70 degrees. The latter represents the lowest inclination acceptable from the Western Test Range without authorization of overflight of South American land mass.

The results of these assessments, coupled with the initial experiment description data received from the experiment studies shortly after the kickoff meeting, led to the selection of a baseline mission concept with a total injected flight system mass of 300 kg and an orbit of 300 km by 1400 km, inclined at 70 degrees. The principal disadvantages of this selected orbit are: (1) the rotation of the line of apsides, meaning that the apogee location is not fixed, and (2) the significant eclipse history that results over the projected 6 month mission duration stresses the profile of electrical power available to the payload experiments.

## 5. MISSION CONCEPT UPDATE TO EXPERIMENT STUDIES

An updated mission concept description was furnished to the experiment studies in January of 2004. Characteristics of a notional STC bus derived from material in the STC study and the RSDO catalogue was supplied as a guide to the range of power, attitude control, command and data handling, and physical interfaces that are characteristic of this class of spacecraft. The baseline orbit and its unique aspects were furnished, as well as a detailed assessment of the radiation environment.

The individual NMP technologists who were the interface between the experiment studies and the mission architecture team passed detailed questions to the architecture team and disseminated the answers equally to all teams. This part of the process served to ensure that all potential users of the NMP ATS were dealing with a common understanding of the STC and the planned mission.

## 6. THE MIDTERM REVIEW

The midterm progress review consisted of a set of presentations from the NMP staff to each experiment study team and a presentation of study progress to the NMP staff. Due to the competitive nature of the process, the interaction was held separately with each experiment team. The NMP content consisted of programmatic direction involving study report contents and handling of cost and risk in implementation planning as well as updates on the sample STC and mission characteristics. Particular attention was directed towards ensuring that the experimenters were aware that the planned class of STC was limited to total payload

capacities on the order of 100 kg and maximum power available to the total payload of on the order of 200 Watts. This distinction was extremely important to ensure that the proposed experiments were aware that they were not the only users of STC services and that this class of vehicle can only support a limited power budget. Attitude control and experiment physical accommodations were also discussed as significant limitations to accommodating multiple payloads.

Updated experiment requirements were delivered by the individual teams that provided encouraging evidence that the communications with the architecture process was working. Mission concept questions were addressed at the review, and further exchanges of individual issues were raised through the communication process after the review. All of this aided the development of a set of experiment study reports that were focused on the level of capabilities that were within the envelope of possible performance for candidate STC designs and which addressed the unique characteristics of the baseline mission.

## 7. EVALUATING THE EXPERIMENT FORMULATION STUDY REPORTS

The 10 experiment study teams delivered their final study reports on schedule in June 2004. The architecture team extracted the mission/STC requirements and planned experiment designs from each of the 10 reports and summarized them to confirm mission feasibility. The question of feasibility had several specific meanings in terms of mission architecture. Specifically:

1. It is desirable for the potential STC (as yet not selected) to accommodate as many individual experiments as physically possible while remaining within broad constraints of budget for the STC and performance capability of the launch vehicle.
2. The process of independent evaluation and recommendation for experiment selection must include awareness of the prospective limitations of the mission concept.
3. Any clear issues of incompatibility among experiments must be identified and presented to the review process to avoid the inadvertent selection of a payload set that cannot be accommodated together.

An enlarged team of four individuals with extensive prior flight project hardware experience was assembled and asked to determine the feasibility of accommodating various combinations of the ten proposed experiments on a representative design similar of the class of potential STC candidates. Their analysis included physical accommodation, required capabilities of power, data

handling, thermal management, and attitude control, compatibility among experiments and compatibility with the baseline mission orbit. The study suggested the following rather liberal constraints on a feasible payload set:

1. No more than 4 experiment payloads in total
2. No more than one experiment from the 3 COTS candidates
3. No more than two experiments from any one of the other three categories (booms, solar panels, and thermal subsystem components)

## 8. CONCLUSIONS

Some key conclusions from our experience with this process are:

1. The use of designated expert individuals as a "firewall" for interface between the mission architecture formulation team and the individual competing experiment formulation teams satisfies the need for information interchange while maintaining the necessary separation between competing teams
2. The existence of a vision and guidelines for a preferred ATS approach is vital to allowing the mission formulation team to provide a broad initial mission concept and allow experiment teams to begin designing to a common envelope of mission and spacecraft performance.
3. An investment in "homework" to evaluate the range of potential candidate spacecraft host vehicles which fit within the cost and schedule guidelines of the program is essential to success of the process.
4. A team of personnel experienced in flight project implementation is essential to monitor the developing mission concept and insure that the developed experiment concepts can be feasibly accommodated by the potential set of host spacecraft in the developing mission concept.

## REFERENCES

- [1] New Millennium Program website, <http://nmp.jpl.nasa.gov/>.
- [2] Herrell, L. M., "The New Millenium Program Architecture and Access to Space," 2005 IEEE Big Sky Conference

## BIOGRAPHY

Philip R. (Dick) Turner holds a MSE in Aerospace Engineering from the University of Michigan (1969) and a BS in Aeronautics and Astronautics from MIT (1968). He has 26 years service at JPL following seven years in the U.S. Air Force and three years in industry. Mr. Turner has served as a system engineer supporting the Galileo and Cassini missions, autonomy technology studies, mission formulation studies, and management of mission proposals. He is currently a Senior Systems Engineer at JPL, assigned as the Project Architect for the New Millennium Program's ST8 mission.

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