

**JPL University Microsatellite Program**

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## Introduction

The purpose of this paper is to share with the community JPL activities associated with micro spacecraft development and the opportunities for involvement by universities. Community understanding will help promote such programs which will lead to enhanced science at substantially reduced prices.

In January of 2003, JPL initiated a University microspacecraft program. That program is currently being funded through the JPL Chief Scientist's Office. Recognizing that many Universities have or are developing microspacecraft programs, JPL is funding a liaison to those programs in the interest of providing technical guidance and mission relevance through NASA identified science interests. In addition, JPL is a strong advocate for University led activities both for potential science and technology benefit, as well as workforce development purposes.

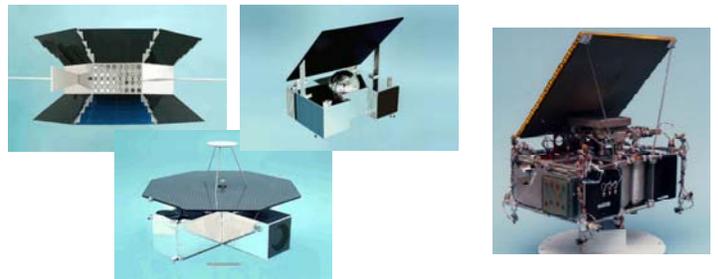
More detail of this evolving program will be presented, along with some background and future directions.

## JPL Background in Microspacecraft Projects

JPL, since the mid 1980's, has been interested in microsattellites and probes for low mass, low power applications. These are especially attractive for measurements requiring very short lifetimes. Early work at JPL looked at miniaturization of avionics, multi-functional structures and micropropulsion as technologies in need of investment to realize the potential these microsats could provide.

In the early to mid 90's a microspacecraft development effort was funded to continue advancing this technology area. Several

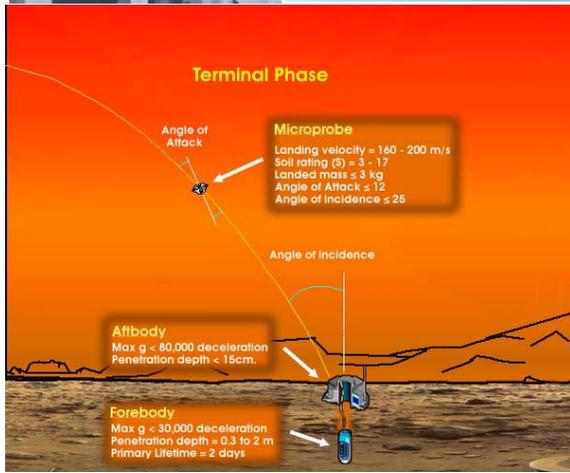
prototype systems were designed, built and tested demonstrating proof of concept functionality, such as the second generation microspacecraft configurations shown below. Due to alternate opportunities insufficient support during this period, many of the key personnel involved left and the effort at the time was absorbed into a larger program and ultimately ceased to exist.



**Figure 1 Second Generation Microspacecraft (SGM) concepts**

Luckily, the effort up to that time inspired a number of independent activities which followed, including the DS2 microprobes, piggy backed on the Mars polar Lander, the Muses-CN micro-rover that was going to fly piggyback on the Japanese MusesC mission, and most recently the joint JPL-Aerospace collaboration flying picosats out of the shuttle using the MEPSI launcher.

In addition to these funded flight projects, JPL has also participated with numerous University efforts. For example, JPL has been coordinating with UCSB to do an inflatable boom experiment. Packaged in a cubesat form factor and weighing approximately 1 kg, it will deploy a 1-m inflatable boom.



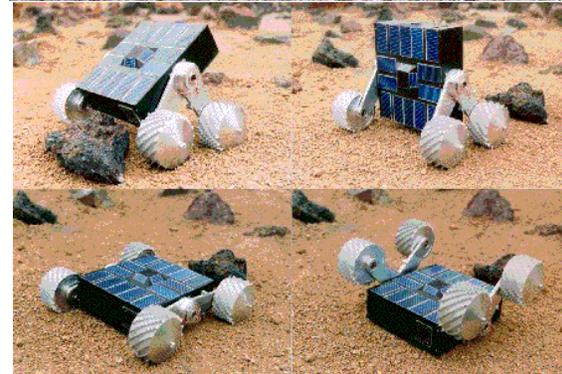
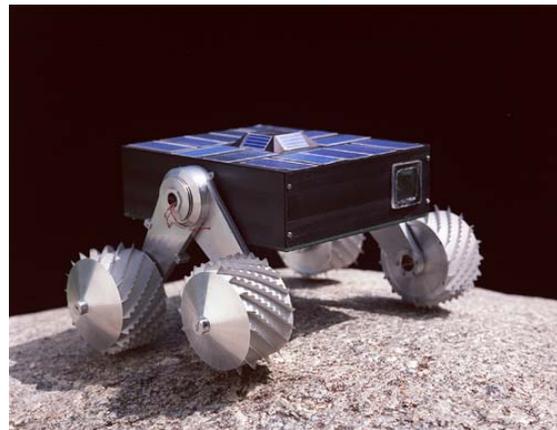
**Figure 2 DS2 microprobes as flown on Mars Polar Lander, 1998**

Besides more formal program activity, many individuals at JPL have contributed to University microsatellite programs directly such as serving as reviewers and consulting. University support also includes such studies as determining Secondary Payload flight options and opportunities; and working on concepts for a future piggy-back Mars opportunities with the Arizona Space Grant Consortia.

In addition to these individual efforts, the Mars program is sponsoring 12 SURF and Space Grant students at JPL for a 10-week program this summer. More detailed information will be provided later regarding that activity.

Much of the JPL collaboration with various Universities spawned from requests following a workshop held at JPL in April of 2002. The

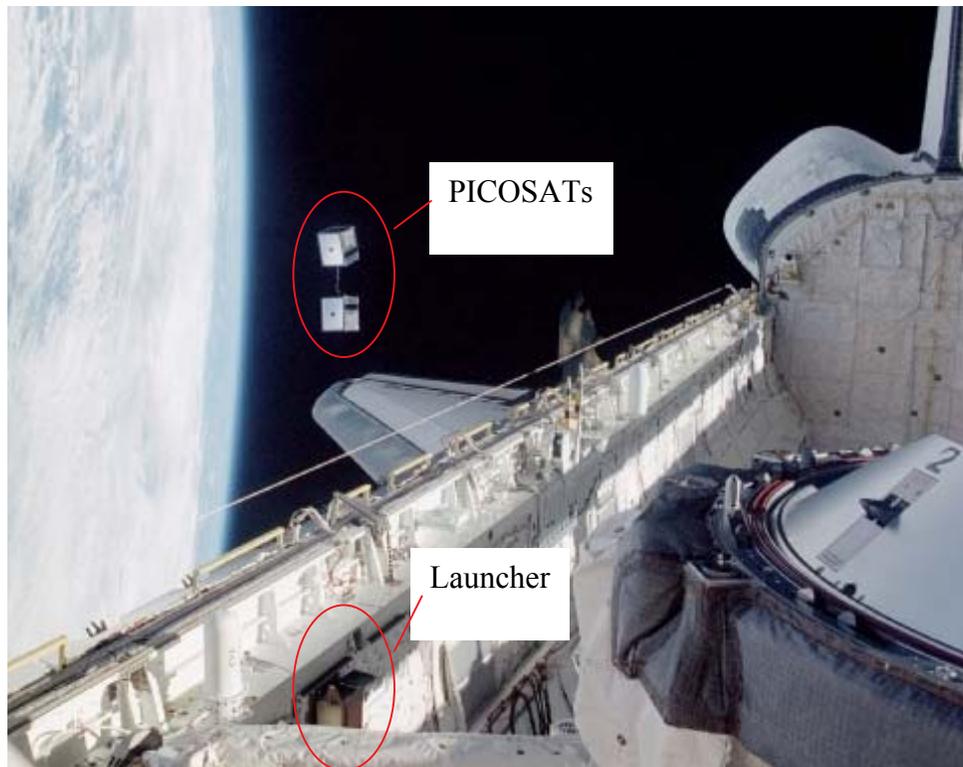
intent of the workshop was to discuss University microspacecraft activities and possible collaborations with NASA. There, Orlando Figueroa, was sufficiently impressed with the University work and plans presented that he offered to fund, in partnership with NASA Code N (Education and Public Outreach), a University Mars Microsatellite Mission as a mission of opportunity on the '07 CNES orbiter. Unfortunately, since that time, the CNES orbiter was cancelled.



**Figure 3 Muses-CN nanorover originally planned as piggyback payload on the Japanese MusesC spacecraft, 2000**

### Why is JPL Interested?

JPL is interested in microsatellite activities for a number of reasons. First, technologies developed for microsatellite applications have broad reaching benefits to all of NASA's missions. Second, the ability to fly multiple small platforms opens up mission



**Figure 4 JPL-Aerospace Picosats launched from the Shuttle, Dec., 2002**

opportunities and science measurements not previously obtainable. Third, JPL and NASA are firmly behind the workforce development results derived from coordinated efforts of this type with University partners. Finally, the teams generated between JPL and Universities have historically proven to be very strong and capable of doing exciting, rewarding space science missions.

JPL is a leading center for space related technology development. A great deal of work is taking place at JPL to reduce the mass, power and volume of common spacecraft components, as well as developing new technologies that provide enhanced and enabling capabilities for space science missions. All NASA missions benefit directly from components and subsystems that are substantially lower in resource requirements. An example of some component technologies under development at JPL are:

Micro and Meso Gyro's

- Micro Sun Sensor
- Miniature Star Tracker
- Micropropulsion
- Microvalves
- Microfluidic and variable emissivity thermal control systems
- Low mass, Low power avionics
- Electronics for extreme environments
- Miniaturized GPS systems
- Miniaturized Mass Spectrometer

In addition to JPL technology development, JPL is interested in technologies developed within the University environment as well. MEMS technologies, software tools, FPGA libraries, micro-thrusters and advanced manufacturing and testing techniques are some of the many areas that will assist the next generation of space science missions to succeed.

Aside from the technology advances, JPL is also researching areas such as rapid

prototyping techniques, methods of cost reduction, formation flying, variations in system level reliability and satellite group behavior.

### **New Science**

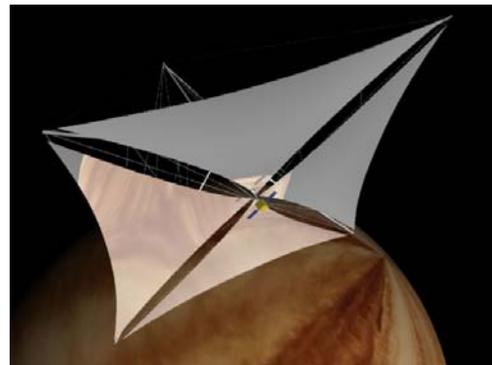
Distributed measurements offer a new opportunity to perform science which has never been possible before. Earth science in particular has been plagued with atmospheric modeling and characterization based upon single-point measurements largely spaced temporally. With revisit times sometimes days apart, diurnal variations in key atmospheric attributes must be estimated and extrapolated. By placing several similar, small satellites into a distributed formation about the Earth, not only can the temporal resolution of these measurements be improved by an order of magnitude or more, but they ALSO provide the opportunity to measure global conditions simultaneously. An example might be a small constellation of 6 or 8 microspacecraft with broadband IR/Visible sensors that measure both the incoming solar flux and the reflected and emitted energies coming off the Earth (affected by variable clouds and ocean conditions). With a global measurement, a more accurate energy balance can be obtained for the Earth and a primary driver for atmospheric activity known much more precisely. This measurement alone will contribute significantly to weather modeling and prediction capabilities.

Outside the Earth, distributed measurements are also needed to characterize the Martian atmosphere, the water distribution cycle and to explain the differences between the northern water ice cap and the southern CO2 ice cap. Understanding and monitoring the atmosphere of Mars will not only help scientists determine the evolutionary cycle that Mars has been through and what future may lie ahead for Mars and eventual manned missions, but also

can provide real-time feedback to spacecraft enroute planning to perform aerocapture or aerobraking upon arrival. Other concepts include microsat busses for solar sail demos, distributed microsats monitoring and observing Near Earth Objects (NEO's), miniaturized probes for investigation of planetary ring systems, and magnetospheric mapping of the outer planets, to name a few.



**Figure 5 Mars Microsatellite Constellation performing atmospheric characterization**



**Figure 6 Possible Heliospheric Explorer using Solar Sails**

### **Workforce Development**

NASA, working closely with Universities, can help foster the growth and education of a highly talented, experienced student body. By providing a rewarding and exciting

educational experience for University students, more young talent will be drawn to space related activities as either scientists or engineers, helping to maintain US leadership in space. This was identified as a critical issue in the recent NASA Strategic Plan. Directly in line with the President's Management Agenda, keeping our young people inspired and motivated in the areas of science and engineering are paramount to the growth and health of the US economy and sovereign interests.

### **JPL and University Partnerships**

JPL has a good track record of mission success working with Universities. Universities have been a large provider for many of the instruments flown on NASA/JPL missions. Teams that are formed between JPL and Universities can draw upon the expertise and strengths of each other to generate highly robust, efficient, cost effective missions. It is highly likely that this instrument providing capability can be extended to complete microsystems and it is desirable to foster this growth.

### **Current Activities**

#### *University Liason*

Beginning in January, 2003, The office of the Chief Scientist at JPL formally initiated a Liaison to coordinate activities of Space Grant Universities who were interested in partnerships with JPL. This newly developed position was established in recognition of the response from University members to the April workshop. A number of Universities, through their respective Space Grant consortia, identified a desire to work directly with JPL and coordinate their microspacecraft activities and studies with the desire to be poised should the Mars opportunity come to fruition.

Currently, the Liason has been working closely with the Arizona Space Grant consortia and specifically with the University of Arizona (UA), Arizona State University (ASU) and Embry Riddle Aeronautical University (ERAU). Discussions are ongoing with Colorado Space Grant, Stanford and MIT, though no current activities are in place with those Universities. The Alabama Space Grant has requested technical support for a growing microsat activity and that activity will commence in September.

#### *Mars Microspacecraft Observer*

The Arizona Space Grant is currently performing detailed studies of a potential Mars microspacecraft observer vehicle. Negotiations are ongoing with the JPL Mars Program office and with the Arizona triad to develop the mission scenarios, requirements and resource constraints that will likely be applicable to such a mission.

This mission concept was one proposed initially, prior to the April workshop, and was well received. Following the announcement by Orlando Figueroa that he would sponsor such a University led mission, many Universities began efforts to assess and begin studies in this area.

At a high level, the mission objectives and constraints are:

The spacecraft will be a piggy back payload affixed to the primary orbiter until the orbiter arrives safely into Martian orbit. The spacecraft, at the appropriate time will separate from the primary vehicle and maintain a fixed standoff distance. Once deployed, the spacecraft will be used to visually monitor and record either the deployment of a large structure (like a deployable antenna or extra solar arrays) or it will be used to observe a sample canister rendezvous experiment, as initially intended

on the CNES orbiter. This data will be invaluable for assessing and diagnosing the sample canister capture algorithms and actual capture / docking event. At no time will the spacecraft pose a risk to the primary asset.

The microspacecraft will have approximately 20 kg and 8 liters of volume on the primary vehicle. It will be able to transmit all data through the primary and is not required to send data directly to Earth.

The mission requirements are very similar to the DoD inspector spacecraft, with the primary difference being the substantially reduced solar flux at Mars for power generation.

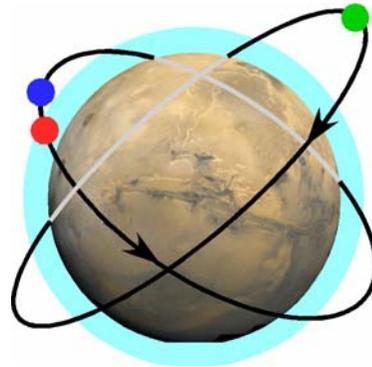
At the end of the summer, the team will generate a report regarding the status of this study.

*Space Grant and SURF Student Internships*  
In addition to this activity, the JPL Mars Program office is sponsoring a collection of Space Grant and SURF students resident at JPL for a 10 week study. This study effort will be focused on a Mars Scout Step I proposal that was dropped just prior to submission due to cost constraints. It has been identified by the MPO as a good case study for the possible use of microsats at Mars.

The mission concept relies on several spacecraft in distributed orbits about Mars performing atmospheric occultations. Spacecraft to spacecraft occultations will provide an unprecedented level of knowledge about the transport of water vapor through the atmosphere and help answer many of the unknowns regarding the hydrological cycle at Mars.

The study has several purposes. Not only is it desirable to arrive at a mission concept that can be proposed successfully at the next round

of Mars Scout missions, but the results of this study will be used by the MPO to assess the value of further investment in microspacecraft technologies. Finally, the summer study can



**Figure 7 MACO Microsatellite concept at Mars**

be used as an investigation into University capabilities to provide future microspacecraft to be used in the roles identified in the study.

This study is the first to use Space Grant and SURF students simultaneously at JPL. There are currently 8 Space Grant students and 4 SURF students. In addition, there is one faculty member resident the entire time who has been sponsored by JPL and the Faculty Fellowship program. Other professors serve as mentors and several faculty members from various Universities provide guest lectures for the study team. The PI is also resident at JPL periodically and participates in the study and interacts directly with the students.

All students receive a stipend for the 10-week activity which is paid for either by the Space Grant of their respective state or by JPL through the SURF program. Students reside in dorms at Caltech for the summer and have an opportunity to take advantage of all that the Caltech campus provides.

While at JPL, the students attend lectures by numerous experts on spacecraft design, mission design, Mars and the Mars Program, microspacecraft concepts and architectures,

various spacecraft subsystems, microspacecraft costs and many more. They are teamed with mentors at JPL who are available for one on one interaction and support. Students have an opportunity to observe and participate in JPL's Team X concurrent system design and engineering environment, as well as the Team I instrument conceptual design team.

At the end of the 10-week program, the students will generate a study report comparable to a Mission Concept Report. They will also provide a short white paper identifying the technologies used and needed by the mission concept that they converged upon. This white paper will assess the technologies according to their current state and identify the extent of the resources required to bring these technologies to a level consistent with that used by the Mars Program.

As a final student exercise, the students will give an oral presentation of their results to a panel of experts at JPL who will review and evaluate their material. By the time the students return to their respective Universities, they will have had a first class mission design experience. Students will learn about all spacecraft subsystems, how all areas interact at the system level, important science needs and requirements that directly dictate mission requirements and how to interact in a fast paced team environment.

### **Planned Activities**

Given the success of the current summer studies, recommendations will be made for future summer study activities. Ideally, two concurrent activities will be held every year. One of those studies would be Code S (likely Mars) related and the other would be Code Y or Earth Science related. All studies will be PI

led and will result in proposals for missions submitted to NASA.

Typical study team sizes will be 10-12 students each and will include assorted faculty participation. The process for announcing these opportunities, obtaining applications and coordinating the participants will be improved based upon the lessons learned this year. Specific improvements have already been identified and the logistics of implementing changes are already under discussion.

In addition to the 10-week summer studies, JPL will continue operating a liaison for any Universities who would like to work with JPL on microspacecraft mission concepts, technologies or simply as a resource for guidance and reviews. In addition, continuing to provide insight on science context for missions or to provide technical support will be beneficial to both parties.

As the JPL internal microspacecraft program grows and funding increases, there will likely follow more funded University tasks. University activities such as system studies, subsystem developments and technology developments are all candidates for directed work. An example of this was a small contract that in place this year with Calvin College in Michigan to perform a low level power system study that will feed into the current JPL Mars studies.

A microsat team here at JPL is currently funded to perform a third, independent study looking at the application of microsat technologies to yet another Mars mission concept. This team will soon be working on other mission concepts as well. The effort is closely coordinated with microsystem technology research and development to help provide mission relevance and requirements to the component technologies being developed. We have a strong foundation for microsatellite

activities and are looking forward to expanding that to include substantial University involvement.

## Goals

There are a number of near term and long term goals for the JPL and University microsatellite activities. In the near term, the results of the three study efforts will be compiled to make a compelling case that a) Microsatellites and microsystem technologies are of enormous benefit to the Mars Program and NASA as a whole; b) Universities are capable and poised to provide full microsatellite systems for incorporation into NASA missions; and c) that the educational experience gained by students involved in these types of activities is unparalleled. Hopefully, the end result will be substantial program funding for continued studies and, more importantly, flight opportunities.

On another front, negotiations are ongoing with the Mars Program office to secure a University payload opportunity on the Mars Telesat mission, slated for '09. Currently, this mission is in the architecture phase and as such this is an opportune time to negotiate payload requirements. After securing payload space on the vehicle, funds will be sought under the auspices of the Figueroa proposal of last year. With the results of the years study efforts and University activities, plus the hopefully negotiated ride on Telesat, we have a convincing case for both Code S and Code N funding.

Discussions are taking place to establish a program for University work. NASA has an opportunity to not only provide mission context for the University community to give their efforts relevance to NASA, but to also potentially coordinate and guide technology development within the Universities. This has the potential for being a win-win activity and

has huge payoff possibilities, both for NASA and for the University community.

Through the ongoing collaborations that will eventually be established between JPL/NASA and the Universities, teams will evolve. These teams will partner with potential customers and submit proposals for future NASA competed missions. A NASA-University program office could operate as the coordinator for these activities and help foster these partnerships.

In the longer term, many hope to re-establish the University Explorer Program (UNEX) with University led missions flown every year or two. Access to space issues, the primary deterrent for the initial program, appear to be making progress. The US is beginning to slowly address the needs of a secondary payload market and new opportunities are steadily becoming available. In addition, several companies are in the process of developing low cost launch vehicles that are compatible with a program of this nature. Within the next two years, there should be launch opportunities for small payloads at reasonable prices. Additionally, if mandated and coordinated properly, NASA could require that all future Earth orbiting spacecraft carry a piggy back University payload.

This follow on program, Microsystems for University Science Experiments (MUSE) can ultimately be combined with the overall NASA-University program, in conjunction with the Space Grant consortia and fly University payloads every year.

Assuming that a vehicle such as the SpaceX Falcon reaches commercial status within the next year, steady state MUSE costs delivering 3 spacecraft every 18 months could be less than 30 million a year.

### Summary

This cost includes program overhead costs, launch vehicle costs, 200K per step II proposal (5 selected each round) and 10M per project over a 4 year cycle (1 year for operations). A more detailed description of this proposed program and associated costs can be provided upon request.

A great deal of activity is taking place at JPL in the area of microsatellite technologies. Program development is underway and University collaboration is growing. The future of this technology area may one day become as revolutionary as home computing.

For more information or to participate in any of these activities, please contact Robert Shotwell at 818-354-6969 or [Robert.Shotwell@jpl.nasa.gov](mailto:Robert.Shotwell@jpl.nasa.gov).

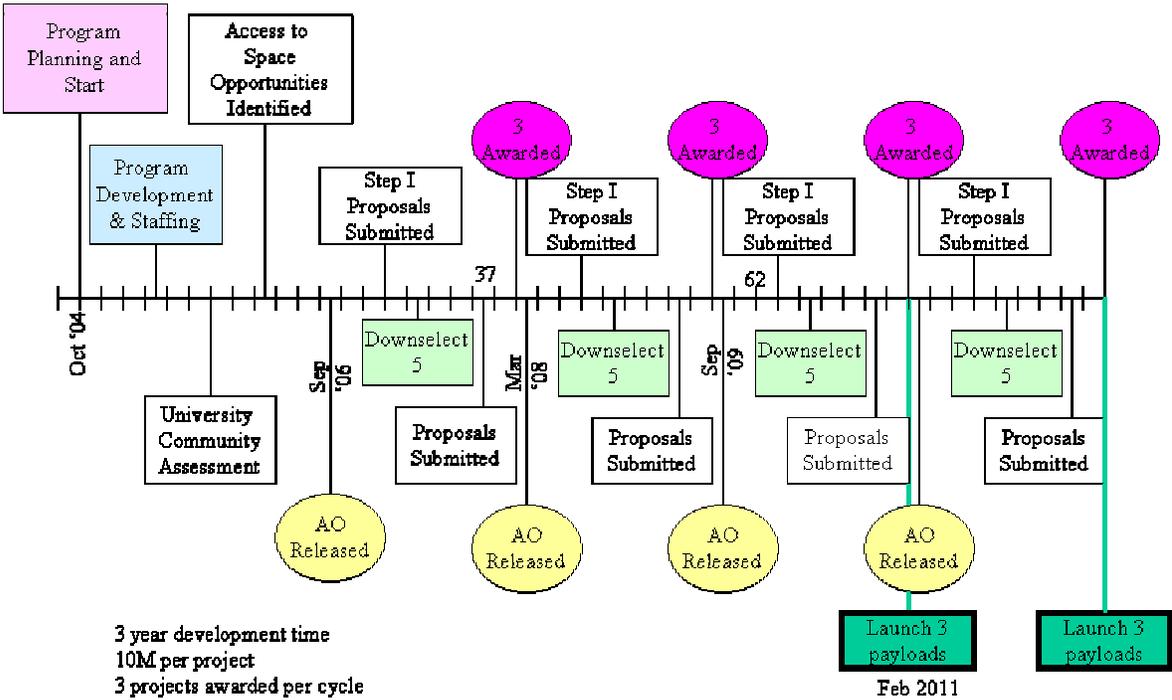


Figure 8 Possible MUSE program timeline