

## The DoD Space Test Program-Standard Interface Vehicle (STP-SIV) Evolved Expendable Launch Vehicle (EELV) Standard Payload Adapter (ESPA) Class Program

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**ABSTRACT:** STP shares a fundamental goal with other government organizations to lower costs and increase speed and reliability of access to space. On the way to achieving this goal, STP is procuring a common spacecraft (SC) identified as the Standard Interface Vehicle. The STP-SIV program intends to shorten acquisition timelines and SC build time, reduce non-recurring costs, applying lessons learned from SC to SC, facilitate payload integration and increase flight opportunities. This program provides for up to six spacecraft of ~180 kg in mass, measuring ~60.9cm x 71.1cm x 96.5cm, with standard interfaces for mechanical, thermal, power and data to support up to four payloads totaling ~60 kg. The space vehicle (SV) shall be designed for orbits ranging from 400 to 850 km, inclinations of 0 to 98.8 degrees, and leverages the ESPA and small launch vehicles. The acquisition approach applies a flexible Indefinite Delivery, Indefinite Quantity (IDIQ) contract for rapid acquisition of SC to quickly respond to DoD needs, uses low risk existing technologies to build low cost spacecraft, and takes advantage of lessons learned from one SV to the next. The design philosophy is to use flight-proven hardware for the SC and developmental hardware only for the experimental payloads.

### INTRODUCTION

STP is the primary space-flight provider for the entire DoD space science and technology community. STP supports the pursuit of basic science potentially beneficial to the DoD, and the reduction of mission risks inherent in technology transformation with respect to space control, communications, geolocation, situational awareness, surveillance and weather.

#### *STP Mission Toolbox*

As a joint, level of effort program, STP provides the critical infrastructure needed to support space-flight experiments in step with the DoD Space Experiments Review Board (SERB) priority, opportunity, and available funding. STP can also provide space-flight and on-orbit operations for DoD SERB experiments and for other US Government payloads on a reimbursable basis. STP has a 38 year history (169 flights, 436 missions as of 12 June 2006) with 90% success.

Prior to the STP-SIV Program, the DoD Shuttle/International Space Station Human Space-flight

Payloads (DHSP) contract was the only mode of space-flight available to STP for meeting low cost, responsive, small experiment requirements. STP typically hosted other small experiments on spacecraft developed on a case by case basis, designed to meet specific orbit inclinations, power, data, thermal, and mechanical requirements and tailored to meet the needs of each payload set. The STP-SIV (ESPA-Class) program adds a much needed tool to the STP toolbox.

#### *Spacecraft Standardization*

The conceptual meaning of spacecraft standardization can have different methodologies based upon standard parts, modules, architectures and interfaces or combinations of each of these methods. STP previously pursued standardization with the Space Test Experiments Platform (STEP) missions. Spacecraft manufacturers offer product lines of spacecraft with common design characteristics for both communication, science and weather satellites. The Centre National d’Etudes Spatiales (CNES) developed the Myriade and Proteus standard spacecraft and have successfully adapted specific payloads to accomplish a variety of scientific missions. Each of these efforts would define

the “standards” in a slightly different manner. STP-SIV is also defining a standard in the sense of an interface between spacecraft and payload and an interface between spacecraft and launch vehicle and applying a variety of lessons learned from previous “standard” spacecraft developments.

### ***STP-SIV Program Goals***

The basic rationale for standardization is the ability to reduce non-recurring cost of subsequent vehicles by performing the majority of the bus engineering and design only once. STP shares a fundamental goal with other government organizations to lower costs and increase speed of access to space. STP’s approach is to concentrate on achieving lower costs and shorter acquisition schedules for small satellite bus development. The primary program objectives are:

- Develop an agile, repeatable, ESPA-Class space-flight capability for DoD space technology demonstrations with a targeted launch readiness date of 2009.
- Develop a non-proprietary standard payload to spacecraft interface (mechanical, thermal, data and power) for use by all experiments hosted on STP-SIV (ESPA Class) program spacecraft.
- Develop flexible capability to launch on a Minotaur-I, Minotaur-IV, other commercial vehicles, or attached to an Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adaptor (ESPA).
- Reduce non-recurring costs through the life of the program through the use of a repeatable space-flight capability, a standard payload interface and overall mission costs through launch vehicle flexibility.

### **ACQUISITION APPROACH**

The specifically designed Indefinite Delivery, Indefinite Quantity (IDIQ) contract, directly supports the Space and Missile Systems Center, Detachment 12 (SMC/Det 12) goal to be a “one-stop shopping” space service “super-provider.” STP-SIV, along with the services of the Rocket Systems Launch Program (RSLP) and the Research and Development Space and Missile Operations (RDSMO) Program, now provide customers with all the mechanisms needed for access to space within a comparatively short time period.

#### ***IDIQ, Contract***

The STP team considered several acquisition alternatives including, the “business as usual” single contract, single contract with multiple options, single award IDIQ contract, multiple award IDIQ and phased

contracts. The only alternative that satisfied all requirements was the single award IDIQ contract.

This acquisition approach:

- Creates a flexible contract for rapid acquisition of satellites to quickly respond to DoD needs
- Uses low risk existing technologies to build low cost spacecraft
- Takes advantage of lessons learned from one satellite bus to the next
- Generates a capability to purchase and integrate space hardware (e.g., separation system, adapter)
- Permits payloads to be integrated from other non-SERB customers
- Has options for multiple spacecraft procurements if needed
- Allows for sufficient security to handle a full-spectrum of future requirements

Funding is the largest constraint that prevents alternate approaches. STP builds space-flight missions from a yearly, prioritized list of 40-45 DoD-sponsored space experiments. Due to STP’s level-of-effort funding, new missions are only started when sufficient funds are available after budgeting for all current missions. This makes the timing and number of space vehicle acquisitions difficult to determine resulting in inefficiencies in the process. Together, the experiment list, which changes each year, and the uncertainty of STP’s funding timeline makes the nature and timing of missions very difficult to predict. Without this knowledge, separate options cannot be priced and, with limited funds, STP cannot support multiple delivery orders from multiple vendors. STP has sufficient funding programmed for the first STP-SIV (ESPA-Class) delivery order (DO). STP expects to have additional funding for a second and possibly third DO and can reasonably expect to acquire funding for one or more DOs from a reimbursable customer.

The space vehicle contractor is required to meet the following program requirements:

- Ability to design, fabricate, and integrate and test two SIVs with overlapping schedules
- Ability to interact with experiment principal investigators and their teams to develop the payload suite for the spacecraft from STP-provided Government Furnished Property experiments
- Ability to handle and process classified information and hardware up to Top Secret/SCI
- Ability to provide up to six integrated space vehicles as defined in the STP-SIV (ESPA-Class) Technical Requirements Document (TRD) and the specific Payload Requirements Document (PLRD) for each delivery order.

**Alignment with Launch Vehicle/Ops Timelines**

Compared to previous STP bus acquisitions, the STP-SIV contract significantly shortens the acquisition cycle and closely aligns mission response times to launch and operations services provided by SMC/Det 12. Source selection is a time consuming and costly activity which previously prevented the ability to obtain spacecraft development services in less than 12 months. The IDIQ contract has provisions to put new delivery orders on contract in 90 days. For payloads that can meet the interface specifications, this ability will significantly increase the speed of access to space.

From on-contract to launch, RSLP can respond within 18 months. This rapid response allows some flexibility in launch vehicle selection while working to obtain launch vehicle partners and more cost effective launch options. Sharing launch costs can save an individual program millions of dollars. Technical and schedule flexibility are key for aligning launch vehicle rideshare opportunities.

**Risk Approach**

From an acquisition perspective, STP is closely aligned with major operational system programs. As such, our approach to risk on the STP-SIV program is similar to major Space and Missile Systems Center missions within the constraints of our budget. This may increase cost compared to some laboratory programs but it provides for high confidence of mission success and reduced risk to experiment operations.

STP requires comprehensive testing and predictable reliability through careful analysis and selection of

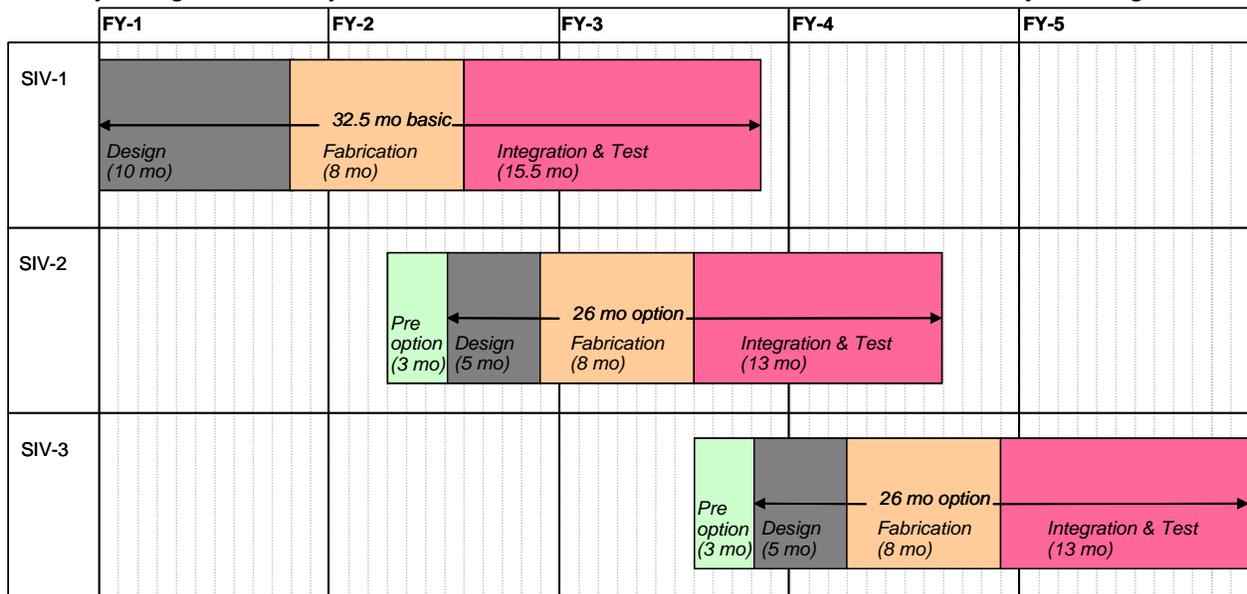
parts, components and manufacturing processes. Where possible, class B, flight heritage parts are used in the design, with exceptions noted and rationale clearly accepted. The reliability description of the spacecraft covers all significant factors impacting reliability, excluding the experiments, and demonstrates an understanding of redundancy, parts selection and up-screening, fault protection, failure modes and effects analysis, as well as failure reporting and correction.

Program test requirements include compliance with updated Mil Standards applicable to science and technology missions. Deviations are carefully considered prior to approval. A full qualification structure test is required for SIV as well as comprehensive system testing, including flight and non-flight software and ground system compatibility.

**Development Timelines**

Over the course of the contract, space vehicle development timelines are expected to decrease from an initial 32.5 month schedule down to 26 months (Figure-1). The primary drivers to the schedule are robust design and test of the first unit, long lead parts and frequency allocation requirements. There is potential for schedule compression with advanced long lead purchases and early frequency allocation coordination provided the necessary funding is available.

A major advantage of the payload to spacecraft standard interface is the ability to add or replace payloads relatively late in the development cycle. As long as the payload meets the interface and can be accommodated within the available margin, each individual mission has the flexibility to manage new or



**Figure 1. Notional Schedule for Multiple SIVs**

changing payload requirements within resource constraints.

Storage capability has also been considered in the program. For several reasons, it may be necessary or desirable to build a spacecraft and store it until a payload or launch vehicle option is completed or identified. For this reason, the ESPA volume envelope will always be considered a constraint regardless of the planned launch vehicle since the actual launch vehicle is vulnerable to change prior to launch.

**BENEFITS AND OPPORTUNITIES**

SIV will provide programmatic benefits for cost and schedule performance over the course of multiple space vehicle developments. Also, using the new acquisition approach will increase flexibility for the mission design process and provide additional space-flight opportunities to experimental payloads.

***Programmatic Benefits***

The SIV program is designed to achieve space vehicle cost savings through production of multiple, standard vehicles. By repeating a proven spacecraft design, the government hopes to save time after the first space vehicle build using knowledge and experience gained on the first run. Mission analysis conducted on the space vehicle will only change as the experiment requirements change. The spacecraft bus will not be affected because of constrained experiment requirements. Also, the SIV program will take advantage of lessons learned during subsequent fabrication processes for the spacecraft and ground support equipment. Additional savings will come from robust testing on the initial spacecraft. The first SIV spacecraft will be tested to the entire scope of the technical requirements, which will encompass various LV environments. This initial spacecraft testing alleviates qualification testing for subsequent space vehicle since the design will be proven on the first vehicle.

Overall, the program office has estimated a cost and schedule saving for the first three space vehicles, Table 1.

**Table 1. Estimated Cost / Schedule Savings**

	SIV-1 to SIV-2	SIV-1 to SIV-3
Cost	20%	30%
Schedule	20%	20%

***Payload and Mission Design Opportunities***

A standard interface provides programmatic benefits, yet operations and payloads receive benefit as well. Although the ground support equipment (GSE) and ground operations systems may need modification due to payload specific requirements (i.e. state of health and science data), the core GSE and ground systems, which interfaces to the bus will not change. Operations training for personnel will remain consistent across multiple vehicles and space vehicle operators will achieve a greater familiarity with the spacecraft and ground system. Hence, GSE, ground system and operations costs are reduced as the number of SIVs increase.

Various publications<sup>1,2,3</sup> reveal the cost benefit of spacecraft standardization. SIV plans to execute standardization at the interface between the spacecraft and payload and the spacecraft and launch vehicle. In order to incorporate the benefits of standardization, SIV engineers work with experiment designers early in the development process. By designing to a standard, the payload developer will understand the resources that are available on SIV and the requirements necessary for payload/spacecraft interface. As part of the SIV program, a payload user’s guide will be published and made available to the entire science and technology community as well as other government and industry organizations. The guide will detail the SIV payload interface. Also for potential payloads, several questionnaires will be required to understand an experiment’s design and operational requirements. In turn, the experimenter will benefit from pre-defined SIV interfaces and components to help bound their interface designs.

Although SIV will benefit from standardization, the STP launch manifest process will receive additional flexibility by using SIVs. The current manifest process identifies an experiment(s), a LV, and a launch date for a complete mission. As experiments begin to design to the SIV interface specification, a higher number of experiments will have the ability to integrate to the bus. This repository of experiments will allow greater mission manifest flexibility. However, this assumes potential experiments have the maturity level that facilitates a schedule advance.

***Lessons Learned/Mission Expectations***

Two lessons learned stand out from previous successful spacecraft standardization efforts.

- The spacecraft should be used for the mission it was originally intended. The performance envelope

of the spacecraft must be planned for from the outset of the program to provide mission flexibility. Following missions must then be tailored to the capabilities of the bus and performance limits sacrificed for standardization benefits in cost, schedule, and reliability.

- There must be demand for the spacecraft capability to realize non-recurring cost savings. Development of spacecraft design standards require upfront investment in order to achieve benefits in the long term. The return on investment is not realized until multiple spacecraft have been built.

Given the analysis of past SERB experiments, the DoD research community is expected to respond with new and innovative experiments that will easily meet the specifications of the standard interface. Researchers have been asking for guidelines and descriptions of interface specifications to design payloads and increase the opportunity for space-flight. Once the interface specifications are published, STP is expecting an increase in SERB experiments fabricated for accommodation on the standard interface vehicle.

## SPACE VEHICLE DESCRIPTION

### Design Set

The overarching driver for the spacecraft design was the STP mission. An extensive analysis of previous SERB payload requirements led to a selection of spacecraft minimum capabilities that would satisfy the largest number of expected SERB payloads. The volume of the spacecraft was constrained by the desire to make it compatible with the ESPA launch environment. Finally, budget constraints limited options like propulsion, higher reliability and longer life which weren't considered a necessity by the majority of experiments.

### S/C Capability

The STP-SIV spacecraft design supports the program goal of a low-risk bus by using flight-proven components, a simple structural design, and significant design and software reuse from prior missions. The design balances a low-cost and low-risk approach with significant spacecraft capability and flexibility.

The STP-SIV capabilities support a variety of potential small payloads. The standard capability spacecraft operates over a range of low earth orbit altitudes and inclinations. The spacecraft design as shown in Figure 2 provides the required power over the full range of sun angles. Mission-tailored multi-layer insulation blankets provide the appropriate radiator coverage for the

particular orbit and payload suite. A single star tracker is a key element of the attitude determination and control system. It is mounted directly on the payload interface plate to minimize alignment errors between the bus and payload.

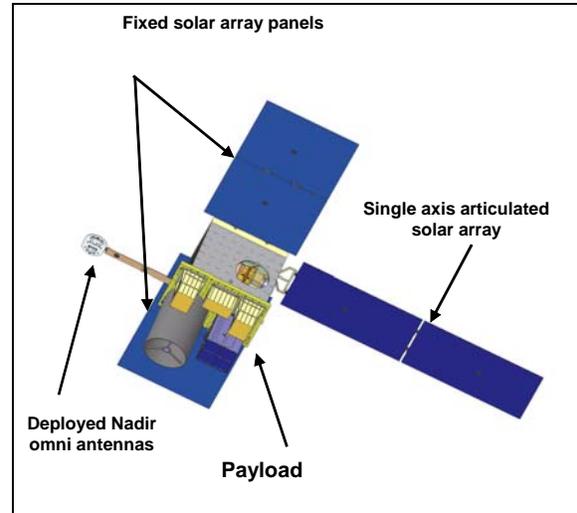


Figure 2. SIV Spacecraft Design

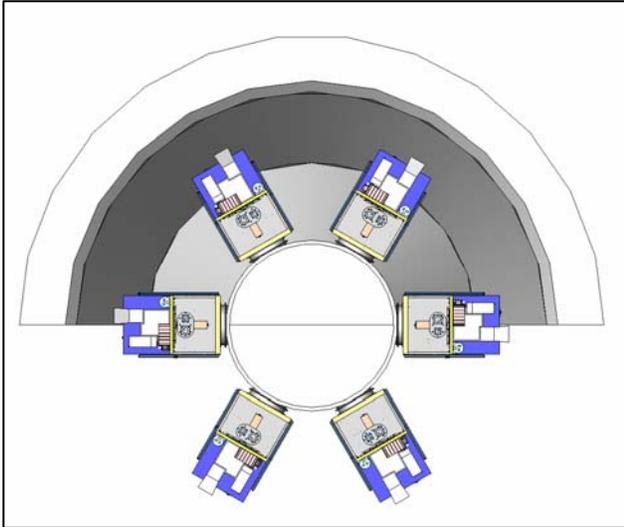
Table 2 highlights the threshold requirements and performance goal characteristics for the spacecraft.

Table 2. SIV Capabilities Provide Mission Flexibility

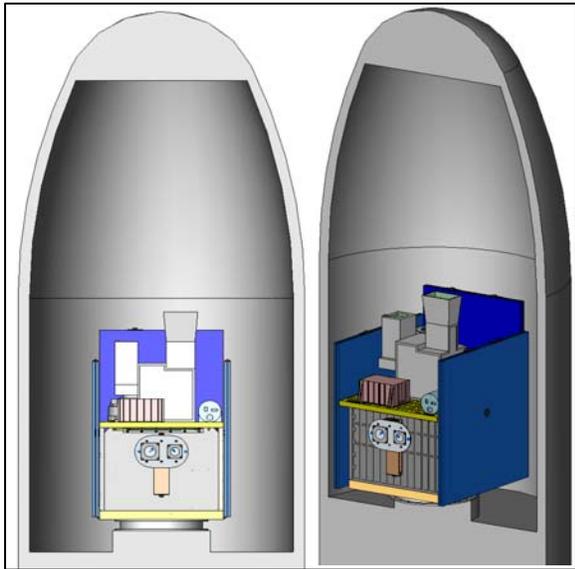
Parameter	Threshold Requirement
Orbit Altitude	400 – 850 km
Orbit Inclination	0 – 98.8°
Launch Mass	≤ 180 kg
Space Vehicle Volume	≤ 60.9 x 71.1 x 96.5 cm
Launch Vehicle Compatibility	Delta IV ESPA, Atlas V ESPA, Minotaur I, Minotaur IV, Pegasus (anticipate compatibility with Falcon 1)
SV Lifetime	1 year
Reliability (at 7 months)	0.90
Stabilization Method	3-axis
Pointing Modes	Nadir, Sun Pointing, Safe
Attitude Knowledge	0.03° 3σ (goal 0.02° 3σ)
Attitude Control	0.1° 3σ (goal 0.03° 3σ)
Bus Voltage	28 V
Communication Frequency	L-Band Uplink, S-Band Downlink
Command Rate	2 kbps uplink
Telemetry Rate	2 Mbps downlink

The STP-SIV design meets requirements for a variety of launch vehicles including the Delta IV and Atlas V ESPA ring (Figure 3), Minotaur I and Pegasus (Figure 4), and the Minotaur IV (Figure 5). The STP-SIV fits

within the limiting-case volume and mass constraints of the ESPA, and will withstand the enveloping launch loads of the launch vehicles listed.



**Figure 3. ESPA Ring Accommodates up to Six STP-SIV size spacecraft (Atlas V Medium fairing shown)**



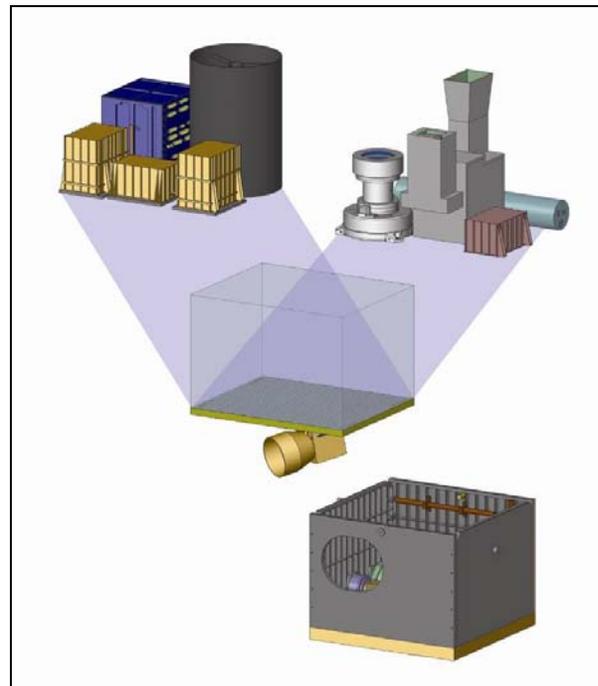
**Figure 4. STP-SIV fits Minotaur I/Pegasus Fairing**

***Payload Interface Specifications/Integration***

The STP-SIV space vehicle is made up of two independent modules – the bus and the payload standard interface module (PSIM) as shown in Figure 6. This approach enables parallel fabrication and integration. The payloads are integrated onto the PSIM independent of the spacecraft bus. The spacecraft bus can be integrated and stored, if necessary, until payloads become available.



**Figure 5. Multiple SIVs fit Minotaur IV Fairing with notional payload adapter**



**Figure 6. Space Vehicle Made-up of Two Independent Modules – Bus and Payload Standard Interface Module (PSIM)**

The PSIM provides the mechanical, thermal, power, and data interface for up to four independent payloads. The design enables management of multiple payloads, and permits identification of secondary payloads relatively late in the program.

The mechanical interface provides a standard mounting grid with pre-drilled holes on 1” centers. Externally

mounted payloads have an unobstructed hemispherical field of view.

The thermal interface provides a means to conduct up to 100 watts of heat from the payloads to the bus radiators which reject the heat to space. The thermal interface maintains the temperature of the interface plate within prescribed limits.

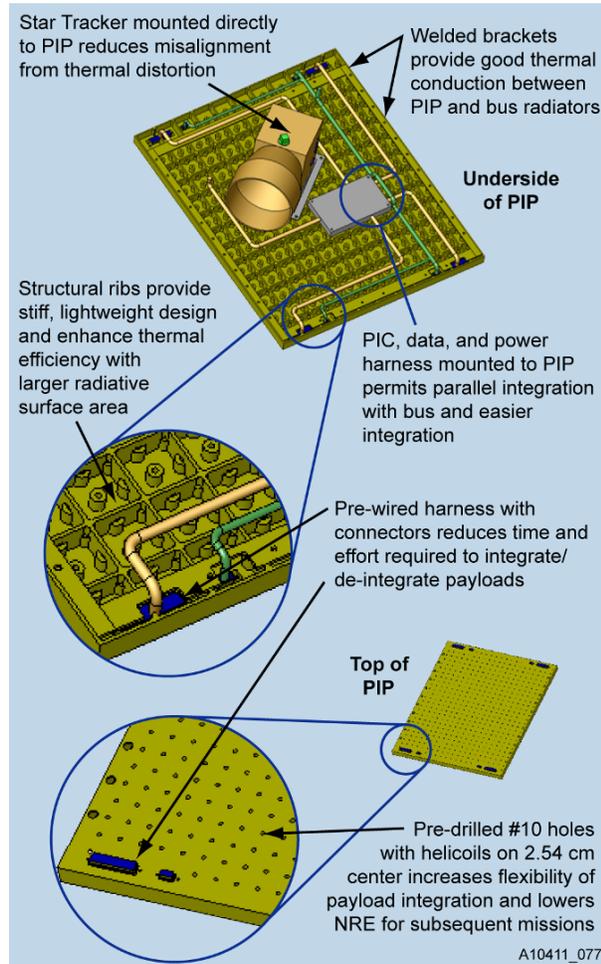
The power interface uses the flight-proven power distribution architecture that is resident in the Broad Reach integrated avionics unit (IAU). To maintain the PSIM modularity and flexibility, each payload is provided three 28V power lines through separate connectors located on each of the four corners of the PSIM.

A payload interface card (PIC) provides an RS-422 connection to each payload to transfer payload commands and data. A standard connector is provided

for each payload to simplify payload integration. The PIC combines analog, discrete, and serial data for the payload suite into a single RS-422 interface, time stamps it accurate to <10 msec, and sends it to spacecraft memory located in the IAU. The data is later downlinked to the satellite control center. Memory allocation for each payload is controlled with parameter tables that can be updated during the mission.

Table 3 highlights the significant parameters associated with the STP-SIV payload accommodation.

The STP-SIV Payload Integrated Product Team (IPT) negotiates payload resource allocation between the payloads including location, field-of-view, harness stay-out zones, data storage and downlink bandwidth, and power duty cycle scenarios. An engineering model (EM) of the payload interface electronics with all interfaces and a spacecraft simulator is delivered early to the payload providers to ensure ease of payload integration.



**Figure 7. Standard Payload Interface Plate (PIP) Provides Flexibility for Ease of Payload Accommodation**

**Table 3. STP-SIV Provides Standard Mechanical, Thermal, Power and Data Interfaces up to 4 Payloads**

Parameter	Threshold Requirement <i>Total for all Payloads</i>
Payload mass	60 kg (goal 85 kg)
Payload Orbit Average Power (OAP)	100 Watts
Payload Volume	0.12 m <sup>3</sup> (goal 0.2 m <sup>3</sup> )
Payload Field of Regard	Unobstructed hemispherical field of view
Number of Payloads	Up to Four
Payload Data Handling	460 kbps from each payload
Payload Data Storage	7.6 Gbit
Payload Digital Command/Data Interface	RS-422 Serial Telemetry and Command, Bi-Level Discrete Output
Payload Analog Data Interface	NLT 8 analog channels per payload for PL Health and Status
Payload Heat Rejection	100 Watts
Interface Temperature	-9° C to +39° C

The modular space vehicle design, the well-defined payload interface, the early check-out between the payload and interface with the PSIM EM, the use of standard connectors on the power and data interface, and the involved payload IPT facilitate a Standard Interface Vehicle capable of efficiently integrating a variety of scientific payloads.

## CONCLUSION

SMC/Det 12 has the mission to provide access to space for DoD science and technology experiments. It is a goal to always increase the number of experiments flown, and the speed at which they have access to space. In order to achieve this goal, the mission efficiency must be increased. Increased efficiency can be achieved by reducing program cost and development time for spacecraft as well as increasing flexibility for launch options. By increasing spacecraft efficiency, SIV has the potential to increase the number of spaceflight opportunities for DoD science and technology payloads. A standard interface provides a means to achieve this goal and provides benefit to the space vehicle acquisition and development, operations, and the payload.

SIV is a transformational capability because it shifts the acquisition process from a custom spacecraft tailored to an individual mission to a flexible, but standardized, platform which has applicability for various DoD science and technology experiments and operational characteristics. In order to increase efficiency in the acquisition process, Det 12 uses a responsive contract approach. Also, lessons learned from the initial SIV will help to reduce design, integration, and testing time.

### *Acknowledgements*

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