Streamlined Payload Processing In The 21st Century

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Abstract. Launching payloads into space continues to be a weekly occurrence around the world. Although it is becoming commonplace, it has not become a low-cost or low-risk, quick and simple process. Out of these conditions, concepts have been developed and efforts are underway to create a generic set of processes and tools that will advance payload processing into the 21st Century by making it more efficient and less complicated. These new approaches are developing more cost effective, shorter cycle time processes, and require fewer resources than in the past. The KSC Center of Excellence for Payload Processing, built on the last 40 years of experience in processing all types of payloads (Shuttle, Expendable, Space Station, etc.), has been addressing these areas. Development is complete and operations are underway on the high fidelity checkout system used to perform final verification of flight interfaces between the International Space Station (ISS) and its science experiments. This system is typical of what has been used in the past for verifying interfaces which include: high, medium, and low rate data communications; video, command and data handling; power; and fluids/gases. The system also contains an ISS Program equivalent ground station, which will receive and process payload telemetry and distribute that telemetry to the appropriate customers. The recently developed concepts and projects underway address the lifecycle of payload processing, integrating agency and customer needs and requirements, and support geographically distributed processing. These concepts have driven out areas of synergy and leverage which enable large improvements to be proposed for payloads headed for Space Station or flying on Shuttle.

INTRODUCTION

Kennedy Space Center is the NASA Center of Excellence for Launch and Payload Processing Systems as well as a Lead Center for Payload Carriers, Payload Processing and Support. To advance the current and future development of payload processing systems and processes, KSC is striving to enhance its capabilities to meet Agency objectives and customer needs for faster, better, and cheaper development, test, and operation of space systems. One of the KSC goals is to utilize its operations expertise in partnership with other entities (Centers, industry, academia), to contribute to the design and development of new payloads, payload processing systems, and new technologies for future space initiatives.

New programs are now baselined and require new approaches to meet program goals while some, like the International Space Station (Jacobson, 2000), require new approaches due to environmental drivers. The new approaches used in Space Station include implementing distributed verification tools, capitalizing on standard services interfaces and functionality, and permitting earlier customer support to allow earlier payload readiness and limit rework and redundancy. This provides more flexibility and services for off-line operations, including location, and the capability for parallel operations in all phases, from post-shipment health checks to final servicing for launch. These capabilities will produce streamlined processes, faster support response, and quicker turnaround and testing times while improving test quality.

With the ongoing development of the International Space Station, Re-invention of the Shuttle Program, expanding base of experienced space customers, new classes of vehicles/payloads like CRV, and 'X' programs, KSC has the opportunity, concepts and projects to move closer to these objectives.

Today's Challenges

Today the pressure continues to increase to reduce the time and effort for customers to reach space. Programs are continuing to pressure reductions in costs for payload processing (programs are pressured to do more with less) and the agency and industry are pressured to reduce the continual recreation in each program of limited, program specific tools and processes. General purpose, configurable and flexible tools which can be reused for multiple programs are needed. Today there are three major programs that KSC is working with:

- The Space Shuttle program is addressing longer program life due to the realities of the major challenges new vehicle designs are facing. This longer life brings the need to reduce time and effort for customers to use the transportation system and to reduce operating costs. Additionally, Shuttle provides an excellent applied 'lab' for new tools, processes and technologies which return real world lessons and better understanding.
- The Space Station program continues to progress to the point of continuous space presence. The reality of continuous space presence brings new issues and challenges that previous 7-14 day mission approaches, tools, and processes will not support. The overall financial drivers push for quantum changes when considering continuous space presence. Highly effective and flexible support systems must be developed.
- The advanced 'X" program efforts are up against technological challenges in propulsion and structures. They also have the advantage of defining the service and cost level requirements for support systems and processes without being limited by today's paradigms and technologies. Payload preparation processes and tool concepts are needed which are highly effective and credible. This allows focus on the major challenges in propulsion, structure and systems.

Past and present activities include efforts toward developing concepts and approaches to meet near term payload processing requirements and build towards the future.

- The Portable Payload Tester (PPT) technology and concept projects and studies brought insight in the duplication and ineffective sequencing of tasks and efforts. (Command 1999a,b) (Davis, 1999)
- Checkout study teams looked at existing tools and processes and have identified areas which would greatly benefit from greater integration between customer, program and processing support areas.
- Shuttle Program reinvention initiatives have brought light to better customer focused and integrated processes. Also, the development of more effective program to processing support tools and technologies.
- The Space Station concept of distributed verification, started early in the program, advanced the understanding of the priority of the requirements within verification in addition to the realities of working in a complex program such as Space Station.
- The Joint Integrated Payload Working Group (JIPWG) is developing understanding of the commonality and differences of the Space Station and Space Shuttle customer processes. This understanding points towards effective, shared, common processes for both programs.
- While applying the PPT concepts to the X-34 program for a minimal processing/launch campaign approach, the benefits of simple tools and sequences were validated.
- Spaceliner 100 new technology calls started with severely reduced time and effort requirements for processing support which drove out the significant benefits of highly integrated tools and processes for all aspects of ground and flight systems and processes.

New Concepts

Out of the past and present experiences, studies and prototypes, four key perspectives have emerged.

- Utilize a life cycle perspective to determine the best tools and processes.
- Focus on the proper processes to perform payload processing in the best and most efficient manner.
- Develop generic tools based on published industry standards.
- Provide the services necessary to properly support distributed teams.

Analyzing and redesigning current processes from a life cycle perspective can address all four of these concepts. (Headley, 2000) By using the systems approach to process design, the suppliers, or payload developers, can be incorporated into the process, resulting in a value chain. Consequently, the problem is addressed in a holistic manner.

One of the primary issues illustrated by this initial analysis was the repeated duplication of tasks and products. The data products that were produced to enable development and testing at the customer facility were also recreated at the launch site. Furthermore, in many cases these data products were also recreated for launch activities and again for on orbit operations. Not only is this extremely inefficient, but it also greatly increases the introduction of errors and the need for additional troubleshooting. The improvements that are made to the data products through testing are lost once the transition is made to a new set of products.

By using a standard set of generic tools, the above-mentioned problems could be avoided. By creating tools that are compatible throughout the lifecycle of the payload, the same data products could be used for the entire flow. Consequently, it would not be necessary to create new ones, and the cumulative benefits from repeated testing would be carried throughout the life of the payload.

Another benefit from the generic tools would be to decrease the errors introduced through the use of improperly designed Ground Support Equipment (GSE). Typically, the customer designs the GSE for developing and testing the payload at his home facility. Not only does this increase the customer's cost and distract him from his primary purpose of creating flight hardware, but it also introduces an additional source of error. Since the same group is developing both the flight equipment and the GSE, an incorrect interpretation in an interface specification will likely be applied to both sets of equipment. Consequently, they will have no problems communicating with each other during test. However, when the flight hardware is connected to the flight systems, the incorrect interpretation will manifest itself resulting in costly troubleshooting and payload redesign. Since this type of problem will not be caught until the payload comes to the launch site, the cost and time to correct it are greatly increased.

The implications of these facts are far reaching. If we can substantially increase the quality of the products delivered to the launch site (payload, data products, etc.) then we can greatly improve the cycle time for payload processing at the launch site. By decreasing this cycle time, we can increase the launch site throughput capabilities while decreasing costs and increasing flexibility. This increased flexibility will be seen in the ability to make changes later in the payload flow, react to manifest changes, and also schedule processing flows more accurately. As process cycle time is reduced, the process time variance should decrease proportionally. This benefit is further multiplied when one realizes that the true effects from process variance are seen in the cumulative process variance. In other words, as the process time variances continue to add serially, the schedules of payloads, or operations down stream are greatly impacted.

The use of a certified checkout system in payload development will drastically improve the quality of the payload upon delivery to the launch site. This is not only because inaccurate interface interpretations will be identified earlier, but also because the time to detect a problem will be decreased. Because it will be possible to detect interface errors very quickly, the time to correct the error will also be decreased. Since, in process terms, the time to learn is equal to the time to detect plus the time to correct, it too will be decreased. The end result is that errors will be caught earlier in the flow, and the lessons learned by the developer through this experience will carry through the rest of the payload development cycle.

One final capability that must be supported is the ability to operate as a geographically distributed team. The launch site must be able to support a "virtual user room" which is independent of physical location. This capability will benefit both the payload developer and the members of the launch site processing team. The customer's costs will be reduced because less travel will be required. The benefit to the launch site will be that the concurrent engineering that is so vital to the quality of the payload will be made easier. Allowing the launch site processing team to have insight into the payload development without having to travel to the payload developer's facilities will allow the launch site to support more customers simultaneously and to decrease travel costs.

PTVS Concepts (Prior to Launch Site)

By looking at the life cycle of a payload, generally three geographic areas become apparent; customer/factory site, launch site, and mission operations site. From the payload processing perspective, the customer/factory site and the launch site exhibit individual and unique challenges. These challenges are addressed within this paper. The mission operations site will be jointly examined with those people more experienced with this aspect of the life cycle.

Portable Test and Verification System (PTVS) is the pathfinder for customer/factory site testing and verification for launch. Tools and processes prior to the launch site tend to be more suited to customization by the customer, and are integrated with other processes and tools the customer uses in preparation for flight. Additionally, more developmental activities occur at the customer site than occur close to launch.

The PTVS is an integrated tool, providing verified electrical interfaces, support for integrated mechanical interface verification and processes and wizards capturing the verification process and expertise for the customer. The PTVS was designed entirely around the process improvements and concepts that it is to support. It will be a small, easily portable system that can be transported to the customer's facility. Once there, it will support all phases of payload design, development, and testing. This support will extend to database development, display creation, and payload unique application support. These data products will be compatible with the systems used at the launch site and on orbit to avoid duplication of effort.

The PTVS will also provide process guidance to ensure a consistent payload development and test process is followed. The system will serve as an extension of the launch site processing team, utilizing an expert system shell and wizards to identify problems and offer solutions. Additionally, the PTVS will serve as a portal for distributed verification, providing location independent access to displays, data, and documents. It will enable extensive use of the web to transfer information and provide notification of updates or changes in requirements, documentation and drawings.

The PTVS will help to provide a substantially higher quality product to the launch site by allowing the payload developer to build to known good interfaces, and test against them early in the payload development cycle. A much higher level of information dissemination will result in a better overall understanding of requirements, and better coordination between all elements of the payload and launch site teams. Finally, the addition of launch site specific skills and knowledge early in the design through the use of concurrent engineering practices will further guarantee a higher quality of product.

These life cycle and process perspectives bring new light to existing approaches and clear understanding of the data product duplicative efforts. The current process of testing data products and interfaces with a high quality verification tool so late in the flow greatly increases risks, and decreases the quality of payload readiness for launch.

Virtual User Room Concepts (Launch Site)

In today's fast paced business environment, there are many drivers that create the need for distributed teams. (Meade, 2000) Global competition is changing the scale of industry, while producing a need for faster turn-arounds, reduced operating costs, operational flexibility, and strenuous technology requirements. New technologies facilitate a global market place with distributed operations, marketing, and sales. For technology based industries, the drivers are much the same. The complex nature of technology is creating a need for highly specialized skills and expert knowledge. Consequently, to achieve faster turn-arounds, reduced operating costs, and operational flexibility with smaller teams, distributed collaboration is inevitable.

Payload operations can utilize Internet technologies to provide greater flexibility in operations, and communication platforms. Realizing the high costs associated with sending large teams of technical experts to the launch site, customers are requesting relevant test data be sent to their home locations. Launch sites must quickly embrace this capability in order to support globally distributed teams for payload processing.

One of the most manpower intensive portions of the pre-launch payload flow is the test and checkout function. This function occurs two and sometimes four times within a single flow. Due to the highly technical nature of this function, it is necessary to have a large number of technical experts on hand to assess payload health, troubleshoot,

and correct identified problems. Based on this, customers traditionally send large teams of experts to the launch site for as long as five-month periods to work side-by-side with payload test engineers.
If these customer teams could monitor the testing activities from their home plant, a large portion of the costs absorbed by the customer could be defrayed. To make this possible, a ***minimum*** of two information flows must be made available to the customer.

- Test data must be sent to the customer's home plant, so that engineering data can be evaluated and the problems understood. This data may consist of displays, raw data, or both.
- As a minimum voice communications between the team members must be made available, so that off site experts can monitor these activities. Additionally, the availability of video showing the work being performed, as well as various views of the payload is desired.

There are many different technologies available to teams in meeting their needs for distributed operations. New technologies are emerging daily to further increase the technological options. The technology is developing so rapidly, in fact, that many companies fear implementing distributed team supporting technologies. However, there are currently several projects in work at KSC to meet these needs. These projects have risen out of individual customer needs and requirements, and still need to be integrated into a comprehensive service. A project is currently being proposed to meet this need. The following is a list of these projects with brief explanations of their function.

- Settebello – provides real-time streaming of audio and video data.
- RUSS – Remote User Support Server for remotely displaying TCMS test system displays.
- PCS Video – remote display of the ISS PCS laptop displays.

It is critical to keep in mind that there are various technical and sociological challenges that face teams working in a distributed environment. These challenges must be addressed in order to enable the team to function properly and successfully achieve their goal. Communication advancements have enabled the implementation of spatially distributed teams. New and evolving technologies augment these capabilities. However, there is no single solution that guarantees a successful implementation. Furthermore, merely throwing technology at the problem may in some cases actually worsen the situation. It is therefore necessary to study the available technologies with respect to their situation specific application in a holistic and integrated way. Additionally, much consideration must be given to the human aspect of the team, and the necessary interaction between team members.

Checkout System Technology Concepts (Launch Site)

When the perspectives of life cycle, process focus, standards based generic tools and virtual user room are applied to the launch site, the launch site becomes more of a natural place for true final departure activities instead of a poor substitute for customer/factory locations. However, for large, complex flight systems such as Space Station, the launch site will continue to be the location for final development and transition to operations activities. Additionally, payloads which are hazardous and require advanced pre-launch servicing type operations will continue to require more advanced launch site support. These new perspectives drive launch site processes and tools to take on 2 distinct yet integrated roles.

First, with payloads arriving in a higher state of readiness for launch, less time and effort is required for low level verification tasks. These tasks invariably uncover problems, issues, and rework that must be addressed with little time prior to launch, resulting in less than optimum solutions. The resulting consequences include: risk of creating new problems when accessing closed out subsystems, re-verification of items disrupted during problem resolution, lack of ready access to skills, resources, and equipment at the customers facility and potentially flying with reduced mission objectives before even getting into space. Additionally, higher levels of confidence for powered up testing with the vehicle are possible, allowing payload and vehicle to be integrated together much closer to launch. Smoother, more natural flow into final count down and launch is achieved allowing increased payload flows for increased launch rates.

Second, even in the case of large systems such as Space Station or payloads requiring more extensive final integration at the launch site, the benefit from the gains made at the customer's site are substantial. Individual subsystems arrive at higher levels of readiness, data products (applications, displays, data bases, procedures, etc.) are

compatible with launch site systems reducing re-work/re-creation and the magnitude of problems to discover and correct (numbering into the 1000s on very large complicated systems) can achieve quantum reductions.

Space Station Concepts

To truly support permanent presence in space and gain the benefit of repetitive visits and shortened turn around times requires the proper processes and tools. Space Station has a start on the foundation of an effective approach. The distributed verification concept has been partially achieved through the development of Payload Rack Checkout Units (PRCUs) in the field and Payload Test and Checkout System (PTCS) at the launch site. These systems begin to provide the basics for supporting highly effective processes for preparing payloads for missions on Space Station.
The concepts discussed in this paper are being applied to Space Station by providing the capability to take portable checkout systems to the customer regardless of geography. This will require a small and truly portable system providing a credible, comprehensive verification capability. Consistent processes must be employed to ensure credible and repeatable results for all Space Station payloads. There must be continuity across all data products to reduce redundant work and introduction of errors through the creation of secondary data products. This will also enable higher quality data products earlier.

It will be critical for Space Station customers to have access to the required special skills and expertise from program, launch site, and other program agents. This closes the loop between processes and tools by providing the proper people with the proper experience. In this partnership the customer gains earlier access to expertise that simplifies their development and preparation for launch. The program gains reduced risk of impacts close to launch, reduced re-work of payload products and enables increased mission returns.

CONCLUSION

To sustain the rate of traffic necessary to return the full benefit offered by permanent presence in space, it is critical that new perspectives are used to produce new processes and tools which credibly meet the needs of the customers and program. Today in all the space endeavors and industry arenas, there are many other obstacles to overcome in rising to the occasion and achieving truly effective routine access to space. There are 2 key principles to understand:

- To choose to allow many obstacles in areas outside the area of direct control to stop efforts in what is within the area of control, is irresponsible. To address one area to the best ability with commitment yields one less problem and is an example to others. Keeping all eyes on the ball in today's world can be one of the most challenging yet critical tasks.
- The concepts and ideas discussed are natural approaches. They require longer-term persistence and effort. The easy obstacles and solutions have been addressed. The remaining challenges will likely require multiple attempts before success. Also, it is a seed planting and tending process, one not done quickly or hurriedly.

The overall space effort is an opportunity of unlimited proportions. There is more to do, achieve and obtain than there are players, also the product of meeting these challenges creates new territory to develop and expand. This area of space exploration requires the best of partnering and teaming, the best ideas and continuous attempts to succeed. That is the nature of this frontier.

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