THE HITCHHIKER'S GUIDE TO I&T

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ABSTRACT

With over two dozen missions since the first in 1986, the Hitchhiker project has a reputation for providing quick-reaction, low-cost flight services for Shuttle Small Payloads Project (SSPP) customers. Despite the successes, several potential improvements in customer payload integration and test (I&T) deserve consideration.

This paper presents suggestions to Hitchhiker customers on how to help make the I&T process run smoother. Included are: customer requirements and interface definition, pre-integration test and evaluation, configuration management, I&T overview and planning, problem mitigation, and organizational communication.

In this era of limited flight opportunities and new ISO-based requirements, issues such as these have become more important than ever.

HITCHHIKER'S HEROIC, YET HUMBLE, HISTORY

The Hitchhiker program was created in 1984 to provide quick-reaction, low-cost opportunities for small payload customers on the shuttle (ref. 1). The Hitchhiker system was designed with standard, basic payload-to-orbiter interfaces and user-friendly customer-to-carrier interfaces. By minimizing payload-unique design and integration requirements, as well as reuse of flight hardware, development time and recurring costs are reduced. Further, "in-house" development, operations, and management at Goddard Space Flight Center (GSFC) has helped to make the Hitchhiker program an extremely cost-effective means of flying payloads on the shuttle (ref. 2).

The first Hitchhiker flight in 1986 was the start of what has been a 13-year history of successful "faster, cheaper, better" service, long before this phrase was even coined. Since then, over two dozen Hitchhiker missions have been flown, involving over 50 instruments. This flight rate has made Hitchhiker indisputably one of the "frequent fliers" of the U.S. manned spaceflight program.

Despite its successes, Hitchhiker has also seen some challenges. While some of these issues are related to the carrier system, others stem from the customer instruments themselves. Many of the customer-related difficulties encountered over the years could have been mitigated with the proper planning, coordination, and implementation.

HINDSIGHT IS 16-28

From the very start of their requests for flight, Hitchhiker customers must consider what special interfaces, services, integration, test and operations requirements will be needed. The more specific and complete the information provided in the beginning, the better prepared the Hitchhiker I&T team will be to "meet or exceed our customer's requirements," as stated in GSFC's new policies based on ISO-9001 (ref. 3).

This means identifying, well in advance, the requirements for:

- Electrical interfaces, such as command, telemetry, recording, and video;
- Mechanical interfaces, like mounting locations, orientation, and handling;
- Thermal interfaces, including heaters, blankets, and mission thermal modeling;
- Ground support equipment (GSE), such as "customer GSE" (CGSE), slings, and containers;
- Instrument servicing, for example, purging, battery charging, and associated accessibility;
- Safety, including hazardous materials and operations, the requirements of which can be found in the STS safety documents (refs. 4, 5, 6);
- Other I&T issues, such as cleanliness, tethering, temperature, and humidity.

These requirements are defined in the Customer Payload Requirements (CPR) document and in detail in the carrier-to-experiment Interface Control Document (ICD).

TO T&E OR NOT TO T&E . . .

To be qualified for flight, customer hardware must meet the qualification and interface test requirements in areas such as vibration, thermal-vacuum, and electromagnetic compatibility (EMC). In the past, some customers have requested that Goddard perform pre-integration test and evaluation (T&E) activities as an optional service. Although GSFC has done its best to accommodate such requests, this practice is generally discouraged due to the limited resources available to Hitchhiker, both in manpower and facilities. Therefore, it is strongly recommended that customers complete all T&E activities (including EMC testing) prior to arrival at GSFC for final flight integration.

Of course, in order for customers to complete a T&E program adequately, the proper verification requirements must be understood. For example, vibration test requirements are generally contained in the GEVS (ref. 7). For EMC, the requirements are defined in the Orbiter/Cargo "Core" ICD (ref. 8). Environmental test specifications may be driven by mission-unique requirements which would be included in the payload ICD.

Besides the usual qualification and acceptance testing, pre-integration testing with the carrier is also recommended. Pre-integration testing provides customers an opportunity to verify function of both flight and ground system interfaces to Hitchhiker. It is usually performed early enough to allow time to make any modifications, if necessary, prior to final delivery. Tests can be performed using prototype or flight hardware (or software) in development, as well as customer ground support equipment (CGSE).

Pre-integration fit-checking of new flight hardware is also a good idea to verify mechanical interfaces to the Hitchhiker carrier hardware. History has shown that, despite the best drawings, actual hardware may not always fit properly. Pre-integration operations also provide an opportunity to verify the accuracy of I&T procedures prior to final delivery.

CM (DON'T SKIP OVER THIS SECTION)

With the introduction of GSFC's new policies based on ISO-9001, configuration management (CM) has become the buzz-word of the day. As mentioned earlier, one of the overarching goals of the new Goddard policies is to "meet or exceed our customer's requirements."

In the case of payloads, this means flying the customer's hardware and completing the mission objectives. To do that, the SSPP needs to fulfill JSC's safety requirements and GSFC's documentation requirements; and to do that, the detailed instrument "as-built" configuration and certification data are needed. More than one customer has discovered that, if their documentation is incomplete, they won't fly. This is because payload design details are required to support flight and ground hazard analyses, as well as provide proof of flight qualification and traceability. In fact, Hitchhiker is now requiring complete flight cert and safety data before integration activities can commence.

Further, a CM program involving complete and organized documentation lends credibility, not only to the payload customer community, but to the Hitchhiker program itself. That is, it inspires a certain level of confidence that the payload integrity has been maintained through a tracking discipline (ref. 9). It also provides an invaluable source of information if troubleshooting becomes necessary. Besides these concrete, real-world issues, lack of payload CM does not meet the new requirements based on ISO-9001.

For these reasons, experiment developers should keep logs and drawings showing the as-built configuration of the instrument. This documentation can help ensure that the payload safety review process, as well as I&T itself, proceeds smoothly. Documentation which is useful to maintain during instrument development includes:

- Test and assembly logs, including records of any anomalies and modifications;
- Certificates of compliance for materials and components, including those provided by vendors;
- Record of Mandatory Inspection Points (MIP's) to verify safety items and as-built configuration;
- Up-to-date mechanical drawings and electrical schematics, including fuse and wire sizes;
- Parts and materials lists, with MSDS's for hazardous materials;
- Fastener certifications and logs, including torque levels;
- Summary of open items, if any, to be addressed following delivery to GSFC.

Upon delivery to Goddard, customers should have this information available for review, along with a summary of any open items or problems which need to be addressed. Examples of archived documentation such as cert logs, problem records, certificates of compliance, and safety verification tracking logs can be provided by the Hitchhiker project upon request.

In an effort to help define customer documentation requirements, the new revision of the Hitchhiker CARS document (ref. 10) includes a list of customer deliverables. Besides supporting safety verifications, deliverables such as a complete set of interface schematics and procedures (both planned and contingency) can help the Hitchhiker I&T team be better prepared to support customer operations.

YOU'RE NOT IN KANSAS ANYMORE

Upon final delivery to Goddard for preflight integration, approximately eight months prior to launch, the customer performs a post-ship stand-alone functional test. This is usually conducted in a class 100,000 cleanroom facility which supports Hitchhiker integration. Throughout preflight operations, the customer's flight hardware may be accommodated with optional services, such as a dry-nitrogen purge. Again, these services would be predefined in the CPR and payload-to-carrier ICD.

Integration of the experiment with the Hitchhiker carrier begins with mechanical integration, such as into a canister, or onto a plate or pallet. All experiment hardware is then electrically integrated with the Hitchhiker carrier, which includes continuity and isolation resistance measurements. After all electrical connections are made, functional tests are performed with the Hitchhiker flight hardware, Advance Carrier Customer Equipment Support System (ACCESS), and CGSE. To help verify command and telemetry interfaces between the ACCESS and CGSE, it is recommended that customers utilize the command status and link status packets provided by ACCESS (ref. 11).

Once all payload components are integrated and thermal blankets installed, the entire payload is moved to the EMC facility for electromagnetic compatibility testing. Usually around this time, telemetry is also recorded for later use during mission simulations. Since these mission sims are usually scheduled in parallel with I&T, customers should plan to deliver two sets of CGSE to Goddard. Following the EMC test, the payload and GSE are prepared for shipment to the Kennedy Space Center (KSC) launch site.

PREPARING FOR THE STORM

Before the payload is shipped, several important areas must be addressed well in advance. First, arranging the transport of some payloads must begin as early as one-year prior to shipment. This is primarily due to strict Department of Transportation (DOT) regulations for shipping hazardous materials. Customers must keep in mind that <u>any</u> hazardous material or item must be identified early enough for GSFC to obtain the necessary DOT approvals, which can take several months to process.

Second, prior to payload arrival at KSC, all planned and contingency procedures should be already approved by GSFC and KSC weeks in advance. In particular, hazardous operations must be submitted to GSFC 75 days before first use. These include everything from lifting and ordnance operations, to use of lasers and high-pressure gases. The deadline is necessary to allow Goddard enough time to review and submit procedures to KSC for final safety approval.

The last "big hitter" in preparation for KSC operations is training and badging. All payload personnel, NASA and non-NASA, must be properly trained and badged to enter and work in facilities at KSC. Two types of badging are in force at Kennedy: one to allow access onto government property, and another to allow entry into designated areas and facilities. The latter requires training for each individual area or facility, and can be either "escorted" or "unescorted."

Since most Hitchhiker customers are one-time visitors, the escorted badging is usually sufficient and does not require any special training. However, if any customer plans to visit KSC several times or for long periods, then an unescorted badge is recommended. Since a constant escort is not required with this badge, it allows more freedom to conduct payload operations in secure facilities. Customers should plan to submit requests for unescorted badging at least a year prior to need.

THE MAIN EVENT

The payload is shipped via an environmentally controlled vehicle to KSC. Following arrival, the payload is transferred to a payload processing facility (PPF), typically a class 100,000 cleanroom. The payload is then tested and prepared for orbiter integration. This includes functional tests of each instrument using the ACCESS and CGSE, as well as a simulated orbiter interface verification test (IVT). Other optional prelaunch operations, such as alignment or instrument servicing, are also performed at this time.

After all "off-line" operations are complete, the payload is typically transferred to the orbiter integration facility via KSC's payload transport canister (for bridge payloads) or by van (for side-mounted payloads). Orbiter integration is accomplished either horizontally in the Orbiter Processing Facility (OPF) or vertically at the pad, depending on schedule and access requirements.

Following orbiter electrical connections, the payload-to-orbiter IVT is conducted. The purpose of this test is to perform the minimum testing required to verify copper path interfaces between the payload and orbiter; it is not considered a functional test. During the IVT, commands are sent to Hitchhiker by KSC from the Launch Control Center (LCC) and monitored by Hitchhiker and customer personnel at the PPF. Command bit patterns are predefined months in advance; therefore, any experiment-specific command patterns should remain unchanged following submission to Hitchhiker.

After the IVT and prior to final payload-bay door closure, close-out operations are performed. These include removing any purge or trickle-charge lines, removing any non-flight covers, and taking payload close-out photographs. Typically, no customer operations are performed in the orbiter unless previously agreed upon as an optional service.

Following the mission, nominal landing is at KSC. The payload is removed from the orbiter at the OPF and is transferred via transport canister or van to the PPF. Usually, no post-flight testing or experiment deintegration is conducted at KSC.

The payload is then shipped back to GSFC for carrier and experiment deintegration, at which time the hardware is returned to the customer. This occurs no earlier than one month after a landing at KSC. Contingency post-flight testing may also be performed at Goddard, if necessary.

"GREENBELT, WE HAVE A PROBLEM."

Any aerospace program can experience technical problems, whether it be a large project involving hundreds of individuals or a smaller one made up of only a couple of dozen. In the latter case, such as Hitchhiker, the efforts of each individual can have an even greater influence on overall mission success and safety. Each team member must help ensure that integrity is maintained and requirements are fulfilled. For customers, this means making sure that their instruments meet all carrier interface and safety requirements.

For example, electrical problems frequently stem from incorrect or inadequate grounding, isolation, shielding or filtering. Consideration of these design issues is particularly important if the experiment hardware includes pumps or power supplies which may induce noise. These issues can be mitigated through adherence to the customer-to-carrier interface requirements specified in the CARS, as well as the EMC requirements of the orbiter ICD. In addition, full functional testing of the instrument and support hardware prior to delivery can help the I&T process run smoother.

Mechanical problems during integration can arise when there is a misinterpretation, or simply a dearth, of interface drawings and dimensional data. For example, interface drawings for a satellite which used the Hitchhiker Ejection System did not clearly show the clocking required for mounting the satellite to the ejection pedestal. This resulted in having to reorient the satellite after integration on the ejection system -- a dangerous task since ordnance had already been installed. Therefore, clear and complete interface schematics are imperative, particularly if no fit checks are performed between the customer and carrier flight hardware.

In addition, parts and materials must be flight-approved with associated certification. History has seen several payloads entirely disassembled to replace fasteners which were discovered to be non-flight. The process involved in obtaining approval to fly hardware with known defects (such as fractures) is usually a more formidable task than simply replacing the hardware itself.

In short, comprehensive definition of requirements and interfaces can help minimize problems and facilitate the I&T process. To this end, Hitchhiker has improved the definition of carrier interfaces with its new revision of the CARS document.

CUSTOMERS ARE FROM MARS, HITCHHIKER FOLKS ARE FROM VENUS

Among all the technical and programmatic issues, by far the most important yet most difficult to achieve is good communication between organizations. It goes without saying that Goddard, like any major institution, has its own share of internal breakdowns in communication. However, the communication between Hitchhiker and the customer is important to address within the scope of this paper.

One area of communication which is critical to successful I&T is the customer informing Hitchhiker ahead of time about planned or unplanned work. While previously approved procedures are important, it is equally crucial for the Hitchhiker team to be cognizant of all payload activities following instrument delivery. Specifically, the I&T manager is considered the single-point contact for all integration and test activities at both GSFC and KSC. The I&T manager must be kept informed of all carrier and experiment plans and activities. This will help ensure availability of resources, proper operational sequencing, and safe implementation.

In the case of KSC operations, good communication about planned activities is especially important to help minimize modifications to documented requirements and approved procedures. Also, since the I&T manager acts as the communication interface between the payload and launch site, customers are requested to go through the I&T manager for special requests to KSC. This approach helps to minimize multiple requests to KSC personnel and helps keep the I&T manager informed about customer operations.

Another aspect of communication which must be addressed is in the area of customer hardware and software configuration management. Besides the as-built configuration and cert data mentioned earlier, post-delivery configuration management of the instruments is also important. For example, customer hardware or software is sometimes modified following delivery in order to effect enhancements or correct problems. Such changes must be brought to the attention of Hitchhiker personnel to ensure that even seemingly benign modifications will not compromise flight safety or mission success.

In the case of the Hitchhiker carrier, hardware and software is controlled via the SSPP configuration management process. Since it does not maintain configuration of customer hardware or software, the SSPP has instituted a process by which modifications by the customer can have greater visibility and review for potential impacts. Following delivery to GSFC, customers are requested to complete and submit a Customer Configuration Change Request (CCCR) for any changes to hardware or software from that originally approved for use. Since the CCCR is used simply as a communication tool, it imposes no new CM requirements on the customer.

Needless to say, the use of CCCR's by the customer can be minimized if the instrument and GSE is delivered to Goddard fully assembled and functional. Since Hitchhikers have, by design, relatively short integration and test schedules, it behooves customers to deliver their instruments and GSE complete and in proper working order. If any "open items" remain to be completed, such as installation of flight batteries or a gas top-off, these should be identified with approved procedures in place prior to integration.

Finally, as part of its commitment to customer satisfaction, the SSPP has introduced a "SSPP Customer Survey" form. This form was designed to provide customers a standardized means of communicating their impressions of Hitchhiker services. Customers are encouraged to submit the survey anytime after deintegration.

IT'S NOT THE SIZE OF THE CARRIER, BUT WHAT YOU DO WITH IT

Despite all the issues presented here, Hitchhiker is still one of the "fastest, cheapest, and best" means to fly shuttle payloads. Although there have been recent increases in documentation and CM requirements, the Hitchhiker I&T process is still relatively streamlined compared to larger payload projects. This allows Hitchhiker customers shorter time between experiment conception and launch, as well as quick return of data.

Customers can help the Hitchhiker team in its continuing effort to improve the I&T process. Examples mentioned include clear definition of requirements and interfaces, pre-integration testing and evaluation, configuration management, adequate planning, and good communication. These efforts can help take Hitchhiker into the 21st Century.

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