# HELPFUL HINTS TO PAINLESS PAYLOAD PROCESSING

presented by

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## ABSTRACT
The helpful hints herein describe, from a system perspective, the functional flow of hardware and software. The flow will begin at the experiment development stage and continue through build-up, test, verification, delivery, launch and deintegration of the experiment. An effort will be made to identify those interfaces and transfer functions of processing that can be improved upon in the new world of "Faster, Better, and Cheaper." The documentation necessary to ensure configuration and processing requirements satisfaction will also be discussed. Hints and suggestions for improvements to enhance each phase of the flow will be derived from extensive experience and documented lessons learned. Charts will be utilized to define the functional flow and a list of "lessons learned" will be addressed to show applicability. In conclusion, specific improvements for several areas of hardware processing, procedure development and quality assurance, that are generic to all Small Payloads, will be identified.

## INTRODUCTION
The opportunity to test theory in space is often the culmination of many years of research and dedication of this nations finest educators, scientists, and research teams. The process from experiment concept through launch and mission operations to experiment results is exciting, rewarding, and often overwhelming. This paper is intended not only to present to the experimenter the overall scope of the process requirements (Figure 1-2), but more importantly to encourage the utilization of the valuable resources available and consider integrating certain disciplines within the experiment life-cycle that have been discovered from lessons learned. The lessons learned experience base from which this information is derived covers over 130 flight experiments aboard 27 shuttle missions.

## THE NASA TECHNICAL MONITOR (NTM) AND LAUNCH SITE SUPPORT MANAGER (LSSM)
The two individuals responsible for ensuring a smooth transition between critical milestones are your NTM and LSSM. Following the submission of your Payload Accommodation Requirements (PAR) an NTM will be selected for your mission. The NTM has the tremendous task of planning and verifying that all of your documentation, experiment requirements, support needs and schedules are in place and maintained particularly during the first half of the experiment processing effort. Once your experiment reaches the launch site, the LSSM assumes this task with direct input and support from the NTM. Their contribution to the success of flight experiments in the past is invaluable. To effectively manage the various aspects of preparation, integration, and support, it is crucial that you remain in close contact with your NTM.

# HITCHHIKER

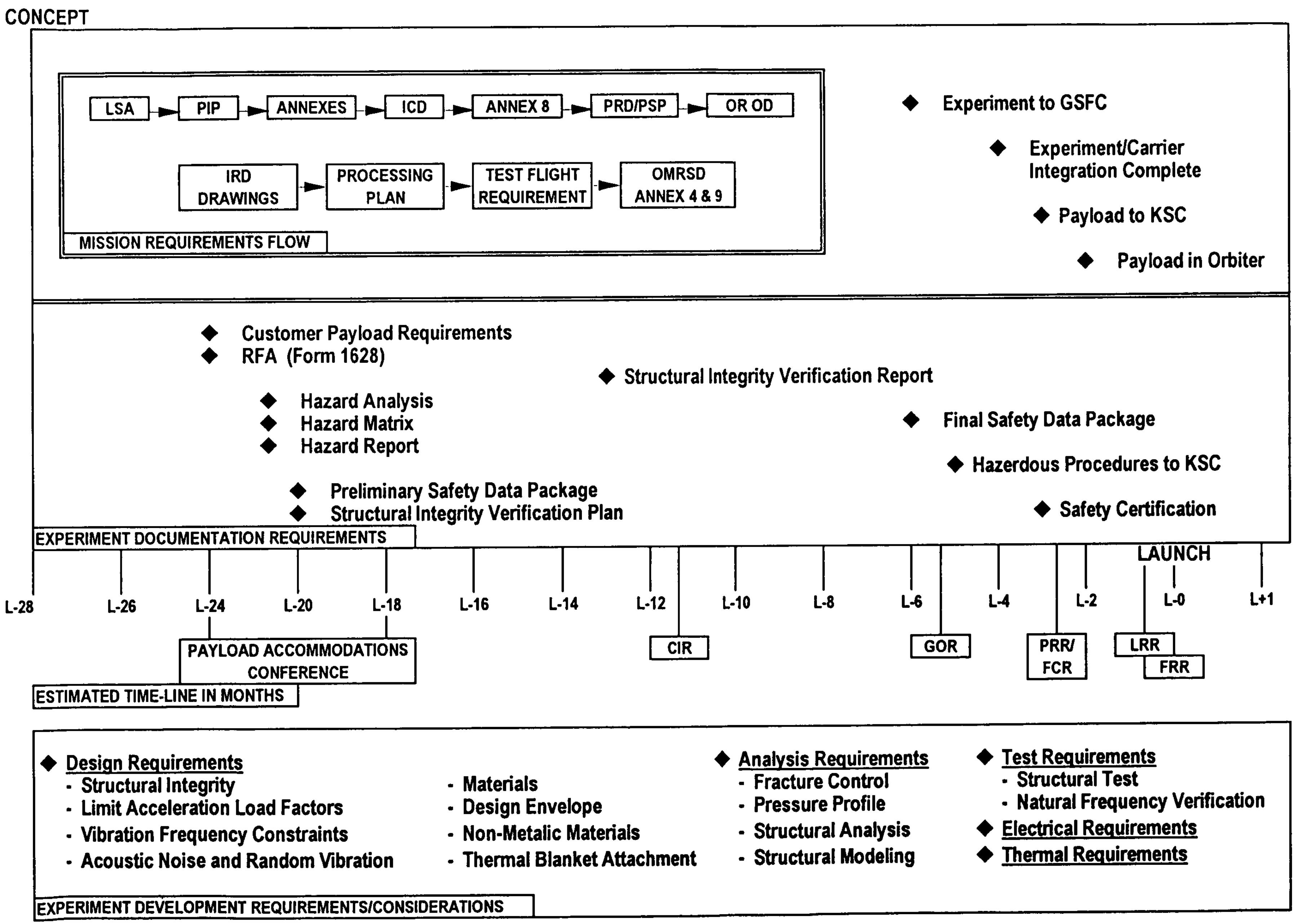



Figure 1.

# Get-Away Special

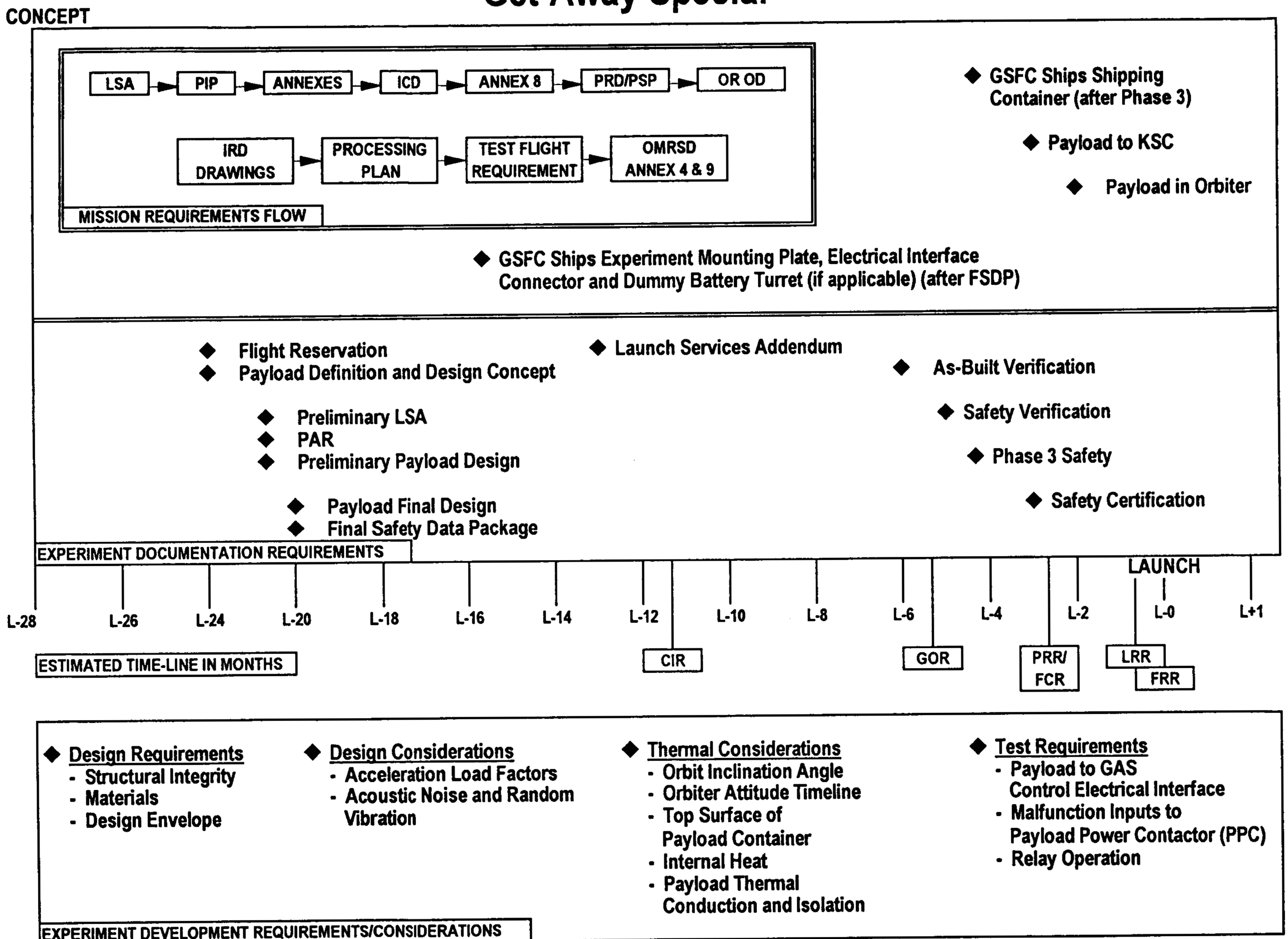



Figure 2.

## DESIGN PHASE

Based on Lessons Learned, there are particular aspects of hardware and software design and development that are sometimes overlooked. Early consideration of these factors can prevent late-stage work-arounds that are time consuming and can dramatically affect the level of integrity of the hardware and/or mission success.

**Replacement/Back-up Parts/Hardware**

During the design and development of your experiment, consider retaining a small stock of critical parts or sub-components vital to experiment function that could easily replace failed units. Long-lead or custom items should be procured with spares in mind. Ensure that the spares have been tested and are qualified for flight. Remember also to bring them with you to the launch-site for contingency use.

**Access to Serviceable Components**

Access to serviceable or system-critical components should be the primary focus in the design of the hardware. The location of batteries, cryogen and pressure ports, film transports, data storage units, drive mechanisms, and thermal control units, are some of the areas of critical failure that could determine the fate of the experiment if there should be a delay in the launch schedule or your experiment fails post-ship functional testing at the launch site.

**Flight Environment VS Test Environment and Vibration & Thermal Effects**

The mission environment can present a host of unforeseen impacts to the proper function of the experiment. Obvious considerations include launch-induced vibrations, and hot and cold-case attitudes, which have been contributors to numerous experiment failures in the past. The orientation of the experiment during launch can cause vibration-induced failures of support structures, component housings, actuators and drive-mechanisms. There are additional aspects of the mission cycle that are rarely anticipated. Events such as crew activity on-orbit can produce micro-gravity upsets that may affect the processing of materials. The experiment may be affected by virtue of its location relative to co-manifested payloads. Thermal extremes may occur as a result of shadowing from larger payloads. Unusual occurrences which have affected previous experiments include the South Atlantic Anomaly which can interrupt and/or corrupt critical data and telemetry functions. While not all impacts can be foreseen, giving thoughtful consideration to certain extremes may provide you with the opportunity to incorporate certain safe-guards within your design to protect your experiment from such events.

**Ground Support Equipment (GSE) Operating Parameters**

A vital component of experiment function is the integrity of the GSE. Having a thorough understanding of its electrical or mechanical influence on the experiment can reduce or eliminate your support hardware as a contributor in hard failures or unexplained anomalies in testing. A primary performance function of electrical GSE is accurate signal generation. Grounding schemes within the support equipment and flight experiment can significantly affect signal quality. Troubleshooting efforts during previous launch site processing operations ultimately resulted in signal spikes, or timing incompatibilities produced by the Electrical Ground Support Equipment (EGSE).

**Limited Life Items**

When selecting certain items for your experiment, determine the survivability of that item under conditions such as the time-lag between final installation and the end of mission. Under normal circumstances, that duration could last as long as 3 months depending upon your installation date of that item. O-rings, valves, seals, film, lubricants, etc. could suffer severe degradation or ultimate failure if installed too soon or schedule slips force a launch delay.

**Weight/Volume Limitations**

Keep in mind the importance of maintaining your estimated payload weight. The experiment directly affects the overall weight and Center of Gravity (CG) of the carrier and could violate requirements established in the Interface Control Document/Information Requirements Document (ICD/IRD) which constrain both the carrier and launch vehicle. The volume of your experiment must also remain within the requirements established by your carrier hardware. Design modifications may contribute to both weight and volume exceedances.

**On-Orbit Input Requirements**

During the design stage of your experiment development, be aware of the extent of maintenance or operational processes that would be required during the mission to ensure proper function and health of your experiment. It may be possible for you to incorporate "self-check and correct" features within your system that would automatically provide protection to your experiment without the assistance of the flight or ground crews.

**Experiment Structural Support**

When designing the experiment support structure it is imperative to verify that it can withstand launch-induced vibration and shock loads in their respective orientations. A vertical support strut will be horizontal at launch and must withstand launch-mode effects without compromise in this orientation.

**Drawings/Historical Traceability**

There is no substitute for documentation that accurately reflects the configuration and history of experiment performance, specifically when an anomaly occurs. During off-line processing it's an invaluable tool for assisting in troubleshooting, oftentimes reducing the extent of tear-down to reveal the source of a failure. But more so, it is a tremendous time-saver in that historical performance patterns often reflected in the data are ordinarily impossible to detect through troubleshooting efforts. Traceability of testing results and configuration also becomes more valuable as your experiment moves through the integration processes with the carrier and ultimately to the launch vehicle. On-line experiment failures involve numerous organizations including co-manifested payload organizations, flow managers and directors, and other NASA centers responsible for mission operations or orbiter integrity. Being able to provide or access accurate and complete data of your experiment will not only expedite the troubleshooting effort for the launch site community but also produce a level of confidence within that community that the experiment integrity has been maintained through a tracking discipline.

**Payload Integration Plan (PIP) and Interface Control Document (ICD) Input**

The top-level controlling documents for shuttle payloads are the PIP and the ICD. Requirements unique to your experiment should be provided to your NTM for consideration and/or incorporation into these top level documents. Special servicing, handling, monitoring, and accessing requirements will be addressed and an implementation approach developed within the constraints of these documents.

## EXPERIMENT DEVELOPMENT & TEST PHASE

The integrity of the experiment resides in the workmanship afforded it, the level of testing performed, and the strict control of configuration.

**Ensure As-Built Compliance to PAR, Drawings and Safety Package**

The largest contributor to the loss of flight-worthy configuration is design modifications. Most changes are likely to occur during the experiment development phase. Ordinarily by this time the PAR has been established and understood, the preliminary design has been issued, and build-up efforts are underway in the development of the final safety data package. As design changes occur it is imperative that they be evaluated against the requirements documents to ensure that the experiment remains within the specified limits of acceptability for flight.

**Materials (Compatibility, Acceptability)**

When selecting materials both for flight and ground support use, special attention should be given to the following situations. Several regulating documents exist that control the level of incompatibility and hazard of materials used for space flight. However, there are instances when materials used independently or combined within your experiment may produce unfavorable conditions for sensitive instruments and systems. Verify that the location, containment and compatibility of your materials will not adversely affect your experiment or the carrier hardware both in ambient and flight environments. Another area of caution when utilizing materials is during on-line operations. Materials used for lens covers, support structures, transport containers, etc., must also meet the stringent cleanliness requirements imposed on flight hardware. Off-gassing fluids and materials that are incompatible with the orbiter or co-manifested payloads will be prohibited. In preparing your ground support equipment and remove-before-flight items, keep in mind the environment in which that it will be used. You may find yourself being denied access to your experiment until your support equipment is bagged, cleaned, encapsulated, or any number of time-consuming corrections are made.

**Payload Orientation Effects During Launch Processing**
Fluid distribution and containment systems, batteries, low-viscosity materials, etc., must withstand a 90 degree change in orientation from the payload vertical axis following installation into the orbiter. It will remain in that orientation until a successful launch is achieved. Nominally the time of orbiter rotation to launch is approximately 5 weeks. However, launch delays and in rare cases orbiter roll-back could extend that duration up to 2 months or longer.

**Detailed Test Objectives/Detailed Science Objectives (DTO/DSO)**
Definitive test objectives should be established during the development and test phase for incorporation into launch-site procedures. A clear go/no-go criteria for experiment performance will eliminate the need to interpret performance data real-time and aid in defining success and failure criteria during carrier and launch vehicle testing.

## CARRIER INTEGRATION & TEST PHASE AT GODDARD SPACE FLIGHT CENTER (GSFC)

**Simulate/Verify Flight Configuration of Hardware and Software**
Once your experiment has reached this stage, there will be a noticeable acceleration of the schedule toward launch. Now is the time to simulate complete command and control capability and verify integrated systems compatibility. An interface verification test will be performed validating system integrity. Within that process, the software utilized at this phase of your experiment testing should also result in the final version for flight.

**Perform Fit Checks**
Non-standard interfaces should be verified through fit checks. Conditions such as the build-up of tolerances can ultimately result in the improper fit, form or function upon final integration.

**Procedure Development**
As the experiment moves into the carrier integration phase of the launch flow, there should be a verification process by which to ensure that experiment unique requirements such as special handling, ESD precautions, or other restrictions are addressed correctly within the working documentation. Involvement in the review process is highly encouraged and could prevent an inadvertent oversight by support personnel who are less familiar with your particular experiment.

**Experiment/Carrier Interface Verification Test (IVT)**
The experiment/carrier IVT is the most critical phase of pre-flight processing. This is the stage of the flow that offers a sufficient margin within the schedule and resource limitations of processing for discovering and recovering from any system failures. It is also the final opportunity to sufficiently test your experiment and its crucial interface with the carrier. Once this phase of testing has been accomplished, there should be few, if any, unexpected “occurrences” following shipment to the launch site.

## CARRIER INTEGRATION & TEST PHASE AT KENNEDY SPACE CENTER (KSC)

**Access to Launch-Site Facilities**
The Launch Site Support Plan (LSSP) is a baseline document that is customized for each mission incorporating inputs provided by your NTM and the LSSM. It is a valuable guide to the processing environment at the launch site and covers requirements for such things as training, security, support, and safety.

**Launch-Site Support Capabilities/Limitations**
In preparation for launch-site processing the experiment should be at or near flight configuration. However, post-ship functional and integration activities may warrant minor adjustments and securing for final integration into the orbiter. It is best to assume that materials and equipment that you may require will be difficult to provide. So if at all possible add them to your shipment of GSE. In the event of an experiment failure in the field, real-time support for equipment and supplies has been provided in the past, but is difficult to arrange in short notice, so plan for contingencies.

**Impact/Affect of External Operations**
Inform your NTM of experiment sensitivities early. Following payload installation into the orbiter, literally hundreds of separate and distinct operations will occur in preparing the orbiter for flight. Generally the payloads are protected from orbiter activity, but there are instances when routine operations have been a cause of concern for experiments within the cargo bay. Operations such as main engine x-rays at the launch pad generated an experimenter request to install a lead blanket between his flight hardware and the aft bulkhead of the orbiter. Co-manifested payloads conducting pre-flight operations may also inadvertently affect your experiment. These issues are ordinarily discussed and agreed upon early in the ground operations planning meetings, but it is always advisable to clarify instrument sensitivities.

**Instrument/Carrier Testing With Simulated Orbiter Power/Signal**
It is crucial to establish an accurate test simulation of the orbiter supplied power and signal generation to verify complete system compatibility. This would include video cabling and monitor or other unique interfaces that will be utilized during the mission.

**Maintain Configuration**
Once the experiment/carrier testing has been accomplished at GSFC, maintain configuration of both flight hardware and GSE. Annoying subtleties between duplicate equipment can cause deviations in the expected results and this can easily be avoided through diligent control of the validated system. This would also include your validated software version.

**Procedures Hazardous VS Non-Hazardous**
Keep in mind that the later in the processing flow that operations are deferred the more difficult they are to get approved. Personnel safety constraints are a large part of the difficulty in requesting late-stage operations. There are firm and heavily enforced requirements in place at the launch-site regarding hazardous operations. The long-pole of the process is obtaining procedure approval which stands at a 45-day minimum prior to first use. Hazardous operations are clearly defined in the KHB 1700.7 and it is recommended that the experimenter familiarize himself with the differentiation between hazardous and non-hazardous operations.

**Contingency Landing Site (CLS), Launch Delay/Slip**
Within the realm of possibilities is post-mission landing at an alternate site. Special thought must be given to the precautionary measures to be taken in stabilizing your experiment, if applicable, and whether equipment and/or support personnel would be required to perform safing operations upon landing.

Launch delays are not uncommon. Any number of factors can prevent the shuttle from an on-time launch. Under this condition, your experiment should be able to sustain relatively minor delays without special consideration. However, in the eventuality that the delay has slipped the launch to several days or even weeks, it may be necessary for you to access or service your experiment. Prepare for the eventuality of late-breaking changes. They are, in more moderate doses, a commonality in this business.

## ORBITER INTEGRATION & TEST PHASE

**Interface Verification Test (IVT)**
The final system validation occurs with orbiter power and signal following payload installation. This is the final test-

hurdle that will verify full-up integrity for mission success. It is also when problems can occur if there was not sufficient testing of the experiment and carrier during off-line operations.

**Remove-Before-Flight Items**
When designing instrument covers, be advised that the removal operations ordinarily occur following installation into the orbiter and therefore requires all tools and equipment to be tethered upon installation or removal from the cargo bay. Designing in a simple handle or eye-let through which a tether could be secured prevents make-shift rigging that may compromise the success of the removal operations.

**Payload Stand-Alone Operations**
Stand-alone operations is a term given to payload autonomous activity once "on-line". As private and comforting as that may sound, it is far from either. Any operations occurring within the orbiter are highly visible, carefully monitored, and generally cumbersome particularly when access support such as buckets or platforms are required.

**Payload Documentation Closure**
It is advisable that prior to launch the experimenter ensure that all discrepancies, failures and action items have been adequately addressed and/or resolved. A brief documentation review provides an additional level of assurance that nothing has been overlooked. It is not uncommon to become consumed in pre-flight operations to the extent of losing sight of some of the details. Through comprehensive planning efforts and periodic checks of hardware, software and documentation status' your attention can stay focused on the more rewarding aspects of flight processing, specifically your experiment.

## POST-FLIGHT DEINTEGRATION PHASE

**Post-Flight Payload Access**
Generally, payload removal from the orbiter occurs a week after orbiter arrival. At that time, depending on the carrier, your experiment may be available to you within the following week. Under certain circumstances, it may be possible to perform an initial visual inspection of the flight hardware shortly after cargo bay doors are opened. This is ordinarily an option if anomalous conditions are suspected.

**Safing Requirements**
Depending on the complexity of your experiment, there may or may not be a requirement to perform safing operations post-landing. This is generally reserved for payloads carrying ordinance, or require flight battery circuit deactivation. If your experiment requires early access, be sure to negotiate options early in your agreement planning phase.

**Shipping and Storage Details**
The concern in packaging for shipment is with hazardous materials. Items that are flammable, corrosive, or toxic, radiation or ignition sources, or other commodities that require protective handling must be packaged and labeled correctly for shipment. They must also be utilized in compliance with KSC Safety, Health Physics and Occupational Safety and Health Administration (OSHA) regulations while at the launch site. Be aware of what qualifies as a hazardous material and the restrictions over their use. This data is available from your LSSM.

**Data Retrieval and Integrity Maintenance**
As important as it is to have developed a flight-worthy experiment that successfully completes its mission, it is

equally important that the experiment results are protected properly after flight. Too often in the rush of accessing mission results, there is a tendency to forgo precautionary measures in the handling, tear-down, shipping, or storage process that can degrade or destroy critical experiment results. Define your protective requirements prior to the launch. Someone else may have the responsibility to deintegrate your payload and ship your data/GSE.

## CONCLUSION

A successful processing effort can be achieved by maintaining control of the hardware, software, and GSE configuration, ensuring compliance to flight and processing requirements, and communicating regularly with the NTM. Items for consideration in formulating processing objectives are summarized for use by the experimenter in Figure 3. The degree of attention provided in each phase of experiment processing builds upon and proportionately translates into a smoother interface and transfer effort. It is evidenced through the lessons learned that when sound processing discipline is installed there is a marked improvement in experiment performance and mission results.

## REFERENCES

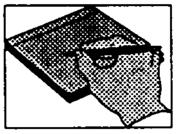
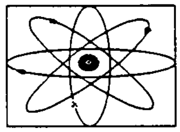
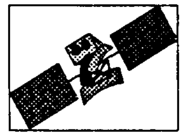

1. NASA Kennedy Space Center, "Kennedy Space Center Operations", KSC FORM 4-607, Revision 1/88.

2. McDonnell Douglas Payload Ground Operations Contractor, "Launch Site Accommodations Handbook for Payloads", NASA K-STSM-14.1 Revision G, August 1992.

3. Rex W. Ridenoure, "Space Shuttle Get away Special Experiment Performance Summary for Missions Through 1991", Ecliptic Astronautics Company Report TR92-002, October 20, 1992.

4. NASA Goddard Space Flight Center Special Payloads Division, "Get Away Special (GAS) Small Self-Contained Payloads Experimenter Handbook", 1991.

# Helpful Hints for Experimenters

| DESIGN | DEVELOPMENT & TEST | CARRIER I & T (GSFC) |
|---|---|---|
|  |  |  |
| | **PLANNING** | |
| ◆ Replacement/back-up parts/hardware<br>◆ Access to Serviceable Components<br>◆ Flight VS Test Environment<br>◆ GSE Operating Parameters<br>◆ Limited Life Items<br>◆ Weight/Volume Limitations<br>◆ Vibration & Thermal Effects<br>◆ On-Orbit Input Requirements<br>◆ Experiment Power, Heat, Data, etc.<br>◆ Carrier Mounting Interfaces<br>◆ Battery Selection<br>◆ Experiment Structural Support | ◆ Understand Operating Parameters of Purchased Components<br>◆ Ensure As-Built Compliance to PAR, Drawings & Safety Data Package<br>◆ Materials(Compatability,Acceptability)<br>◆ Payload Orientation Effects During Launch Processing | ◆ Simulate/Verify Flight Configuration<br>◆ Contingency in Schedule for Problems/Failures<br>◆ Perform Fit Checks |
| | **DOCUMENTATION** | |
| ◆ Payload Accommodation Requirements<br>◆ Flight Reservation<br>◆ Launch Services Agreement (LSA)<br>◆ Hazard Assessment<br>◆ Hazard Control Verification<br>◆ Preliminary Safety Data Package<br>◆ Final Safety Data Package<br>◆ Flight Certification<br>◆ PIP/ICD Input | ◆ Complete Safety Data Package<br>◆ Materials (MUA, Shipping, MSDS)<br>◆ DTO/DSO<br>◆ As-Built Verification For Phase 3 Safety<br>◆ LSA Addendum<br>◆ Input to PIP Annexes | ◆ Experiment Carrier IVT |

| CARRIER I & T (KSC) | ORBITER I & T | POST-FLIGHT DEINTEGRATION |
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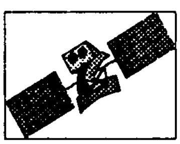
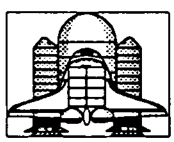
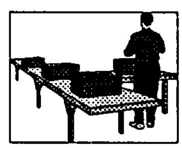
|  |  |  |
| | **PLANNING** | |
| ◆ Access to Launch-Site Facilities<br>◆ Launch-Site Support Capabilities/ Limitations<br>◆ Impact/Affect of External Operations<br>◆ Instrument/Carrier Testing With Simulated Orbiter Power/Signal<br>◆ Maintain Configuration | ◆ Remove-Before-Flight Items<br>◆ External Impacts: Temperature, Humidity, Welding, X-Rays, etc.<br>◆ Payload Servicing | ◆ Post-Flight Payload Access<br>◆ Safing Requirements<br>◆ Shipping and Storage Details<br>◆ Data Retrieval & Integrity Maintenance |
| | **DOCUMENTATION** | |
| ◆ Procedures Hazardous VS Non<br>◆ EEOM,TAL,DFRF,Launch Delay/Slip | ◆ Payload Stand-Alone Operations<br>◆ Payload Documentation Closure | ◆ Payload Special Handling Instructions<br>◆ Shipper Including Special Instructions |

**Figure 3.**