Introduction

In the history of humankind, every space adventure, great or small, has begun on the ground. While this seems to be stating the obvious, mission and flight hardware designers who have overlooked this fact have paid a high price, either in loss or damage to the hardware pre-launch, or in mission failure or reduction. Designers may risk not only their flight hardware, but they may also risk their lives, their co-workers lives and even the general public by not heeding safety on the ground. Their eyes may be on the stars but their feet are on the ground!

This discussion applies to all forms of flight hardware from the largest rockets to the smallest spare parts.

Typical Ground Safety Issues

A very common issue that the Ground Safety Community encounters is lack of recognition of the need for ground safety documentation and reviews. This is most often expressed as "What do you mean I have to get ground safety approval?" Many designers feel that if the hardware is safe to fly, it should also be safe on the ground, or that the safety processes used during development and manufacturing are sufficient for use at the launch and landing sites. Of course this is not true. At most of the world's launch sites, processes exist to assure that the hardware, it's Ground Support Equipment and operations are in compliance with requirements applicable to that site. It is not that the sites do not trust the hardware; it is more the case that, up until the delivery, the hardware has the privilege to be a stand-a-lone process. Upon arrival, the hardware enters into an integrated environment often consisting of the general public, other flight hardware, and facilities. The safety approval processes are structured to provide assurances to all interested parties that the risk is acceptable or has been controlled.

There is also a tendency for hardware owners to pay less attention to the ground support equipment than to flight hardware. This is understandable as the flight hardware is what the mission is all about. However, this can lead to situations where the ground support equipment is not adequate for the job or, at best, has been inadequately analyzed for the role it is to perform. The misuse of commercial-off-the-shelf (COTS) equipment is also a major concern. This occurs when a program purchases COTS and then modifies it to meet their needs. Of course, this then shifts the equipment out of the category of COTS and into a self-built category of equipment requiring a full analysis. When such cases are discovered, there is a mad scramble to get the equipment reviewed and approved. This has the potential to delay processing and a possible impact to launch.

An important requirement many projects tend to overlook is the use of written procedures. Written procedures are critical in assuring that operations are run in the manner that the test team has intended. The lack of adequate procedures or, worse yet, the failure to use written procedures has been listed as the cause of numerous accidents. The timing of the production of procedures is also important. A procedure that is hurried through development and review and is issued just prior to the operation can be just as risky as no procedure at all. An example of this is the Apollo I fire, when the procedure for the "plugs out" test had hundreds of changes made to it and was issued the night before. This essentially meant the test team was seeing the procedure for the first time during the test. The use and control of written procedures can not be over-emphasized.

Hardware providers must make special considerations while their hardware is in the ground environment. These considerations cover such areas as:

- Contingency Planning – Unexpected events, whether external to the hardware, such as heavy weather, or internal, such as a propellant leak, must be planned for so when they occur prompt corrective action is taken.
- Tools – the proper design and use of tools is important to complete pre-launch processing. The accounting for hand tools is critical so they do not become part of the flight hardware.
- Chemicals and Biologics – It is commonly accepted that these commodities when contained in experiments present hazards to the flight crews; however, their handling on the ground present different problems which are often overlooked by developers. This generally applies to sample preparation or return. Because during these times, the commodities are outside their containment. These same issues also apply to the return of trash.
- Mechanical Systems (Pressure/Ordnance/Deployable) – All of these systems contain stored energy which must be released in a controlled manner at the proper time. This is often accomplished through the use of inhibits. The status of inhibits on the ground must be carefully tracked in order to not inadvertently activate the system.

In summary, when ground processing flight hardware, the same level of vigilance is necessary as is applied to flight operations.

The Commonality or Uncommonality of Ground Standards

Depending on the location of the ground processing, a hardware provider faces a myriad of processes from none to complex. This is a reflection of the fact that processing sites are owned and operated by nation states, who expect their laws will apply. In spite of the fact that the processing of flight hardware and its ground support equipment has developed in a somewhat standard process, the requirements among the various sites have continued to be independently developed and applied.

One exception to this is the human-rated International Space Station Program. Three of the processing sites, Kennedy Space Center (KSC) in the USA, the Guiana Space Center (CSG) in Kourou, French Guiana, and Tanegashima Space Center (TNSC) in Japan, use the same document as the basis of their requirements with each site adding their own local requirements. This document was originally written for the US Space Shuttle and was based on U.S. Air Force Range requirements. So there exists now a string of related requirements which can serve as precedence.

For the expendable launch vehicles, the applicable requirements remain site specific. The cause of this is related to the large amount energy in these vehicles and the potential for harm to the general public. It is this public safety facet that makes the processing sites reluctant to adopt outside standards. As a reminder for those programs that operate on both human-rated and non-human-rated vehicles, when on the ground, neither the flight hardware nor the ground support equipment cares what it is flying on; meaning that the requirements for ground processing safety are generally the same regardless of vehicle.

Across the various processing sites, there is a fair amount of commonality in the design requirements however; the rules governing operations across the sites tend to be unique, reflecting their national character. This makes the issuance of a common standard difficult. Adding to this difficulty is the reluctance of processing sites to accept hardware without completion of their review process. One area that may serve as a seed for commonality is the use of COTS. These items are used around the world in non-space applications without further review. An agreement by the launch sites to determine a list of acceptable testing/approval agencies for COTS and then accept them for use without further review would be helpful.

This brings us to the topic of an ISO Standard. There currently exists a three part ISO Standard for space systems (ISO 14620 – Space systems -- Safety requirements -- Part 1: System safety; Part 2: Launch site operations; and Part 3: Flight safety systems). To my limited knowledge, the issue with these standards is that their development does not appear to include the very programs that would make use of them. I believe this is based in part to the strong aspect of national ownership of the sites as previously discussed. The ISO Standards, along with the discussion of COTS above, could serve as a basis for a common standard both internationally and intranationally.

The Cost of Lack of Commonality

The cost of this lack of a common ground safety standard is primarily borne by the payload and cargo community. The launch vehicle community tends to be fixed based and is not easily moved from site to site. The costs incurred in complying with individual sites safety requirements can be minimized by ensuring the site is included early in the mission process. However, designing payloads and cargos to support individual sites can prevent the development of common spacecraft buses and associated ground safety equipment that are universally acceptable. It is this hindrance of cost savings through commonality that is the true cost.

Conclusion

In order to increase the efficiency of ground processing and thereby drive down costs, a universal standard covering ground safety requirements and processes is required. There are processes at work now such as the ISO Standard and the International Space station processes that can serve as the basis for such a common standard. If we can develop a standard for ground safety, can one for flight be far behind?

Ground Safety Issues

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Typical Ground Safety Issues

- Need for Ground Safety Approval
- Flight Hardware vs. Ground Support Equipment
- Written Procedures
- Special Considerations
  - Contingency Planning
  - Tools
  - Chemicals and Biologics
  - Mechanical Systems

Ground Standards

- Site dependent processes
  - ISSP
- Human-rated vs. Non-Human-rated
- Commonality of Standards
  - Uniqueness
  - Commercial-Off-The-Shelf Equipment
- ISO Standard 14620

Cost of Uncommonality

- Primarily borne by payloads and cargos
- Minimize through early contact with Approving Authorities
- Hindrance of commonality

Summary