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Industrial engineering is front and center in space shuttle safety at NASA

BY SANDEEP WILKHU AND JAMES T. BROWN

Historically, NASA has aggressively expanded initiatives to improve safety in the space shuttle program. One such initiative was Industrial Engineering for Safety, which was created to make improvements across the NASA hierarchy of safety by focusing on human factors and man-machine interface points. The program has been notably successful in funding and managing safety improvement initiatives across the country.

The IES program is unique in its approach to reducing risk for the space shuttle work force and flight hardware at the various NASA centers and contractor locations. It identifies funds and manages projects that use industrial engineering methods to improve safety. Since its inception in 2000, IES has made significant strides in reducing risk and improving processes. It has provided line workers an opportunity to participate in developing solutions that improve their work environment and help them perform their jobs more safely and efficiently.

Hierarchy

A four-step hierarchy prioritizes NASA's safety concerns: the public, the crew, the work force, and capital assets.

The IES program provides the space shuttle program with a high return on investment by funding projects that are low cost, high value, and short in duration. The quick-turnaround philosophy allows minimization of red tape that is embedded in the standard project approval process. And line workers have unhindered access to the space shuttle program to address small but high-value opportunities in space shuttle work force and hardware safety improvements.

This approach has brought forth an abundance of ideas and concepts for increasing safety by technicians and engineers who possess intimate knowledge of their work areas and disciplines. IES has partnered this knowledge with conventional engineering methods and tools as well as state-of-the-art virtual reality design tools. This has allowed design teams great flexibility in modifying equipment designs based on user (technician and engineer) input.

The IES program has been a primary risk reduction avenue for space shuttle program technicians and engineers eager to develop and implement improvements to worker safety, flight hardware safety, and processes.

During space shuttle mission STS-93 in July 1999, a main engine controller wire short-circuited during the ascent phase of flight. The cause of the failure — cracked insulation in electrical wires — spurred NASA to re-examine all aspects from design to

operational processes that could contribute to this type of failure. One of those aspects was a processing environment that was not always as worker-friendly as it could be. Historically, the challenge of space flight's high energy and harsh environment has yielded spacecraft that are difficult to process because the design criteria has to be performance-driven, often at the expense of process flexibility. This challenging work environment was seen as one of the contributing factors to cracked electrical insulation.

NASA leadership looked beyond the scope of this specific problem to a much broader challenge. That challenge is a common one for large organizations that manage multi-million- and multi-billion-dollar initiatives: How does the organization identify and fund small, common-sense projects that often exist beneath the threshold for new funding consideration but exceed or are out of scope of the sponsoring organizations operational budget?

The space shuttle program created the IES initiative for this specific purpose, instituting a sub-level board with its own budget to solicit, identify, and approve projects that ordinarily do not warrant high-level attention because they are not major program issues.

Goals

The purpose of the IES program is to identify and reduce risks to personnel and flight hardware caused by human or process error by optimizing human-system interfaces. IES projects will reduce the risk to the work force, reduce the risk of collateral damage to flight hardware, increase maintainability, and improve overall processing of flight hardware and vehicle systems.

The IES goal is subdivided into supporting goals of safety improvements, collateral damage reduction, maintainability improvement, ease of implementation, space shuttle program relevance, and cost savings. The program includes a representative from every space shuttle elements design center, the major space shuttle contractor, and an independent NASA quality representative.

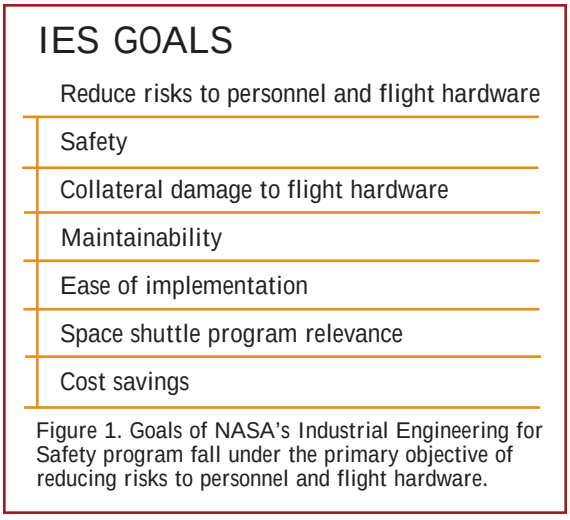


Figure 1. Goals of NASA's Industrial Engineering for Safety program fall under the primary objective of reducing risks to personnel and flight hardware.

Given the maturity of the space shuttle program, deriving the greatest benefits requires that improvements from funded projects are realized quickly. Therefore, activities funded by IES are low in cost, short in duration, and high in value. On average, an IES-funded project costs approximately $550,000 and takes one year in duration, and its value is high in terms of proactively mitigating risk and improving employee morale.

The IES program developed a set of defined goals that were used to communicate its purpose and its basis for selecting projects to space shuttle program stakeholders. These goals ultimately ensured that only the projects that meet the needs of the IES program would be funded. In its first project selection cycle, the team selected projects that were of short duration and high value relative to cost. This was a strategic decision to demonstrate to the space shuttle program community the value of industrial engineering projects. The decision also highlighted that there were many potential projects that could contribute to NASA safety goals. This strategy has proven effective, resulting in continued and increased funding of the IES program.

Project selection criteria

The IES program established a project selection method that is based on the analytic hierarchy process, a value-based decision tool. This selection method forces clear, concrete definitions of IES goals and provides weighting factors for those goals. It allows voting members to represent the perspective and realities of their constituency, providing for an excellent cross-section of the agency, including safety and quality assurance (Figure 1).

The goals and the corresponding priority weights are posted on the secure IES Web site, and all potential project sponsors can view the criteria on which their projects are evaluated. Before voting takes place, potential projects are screened to ensure that they meet the basic purpose of IES and that the decision package is complete and thorough.

Once this is achieved, the project sponsor briefs the IES board on the project and addresses any questions they may have regarding the project. IES board members then vote on the proposed project using the analytic hierarchy process. Each new project is compared to two projects that collectively represent the reference (or "gold standard") for an IES project. This standard ensures continuity in voting and becomes a complete record of the scores of all funded and unfunded projects that are comparable from year to year.

It allows the IES leadership to fund projects that may have scored well in a previous year but weren't initially funded due to budget constraints.

Results and examples

In 2004, the IES program budget received a 50 percent increase to $15 million annually from the previous annual authority of $10 million; as a result, there have been some very good risk reductions to the space shuttle work force and its hardware. In the program's five-year existence, the core team has approved more than 100 projects and studies totaling approximately $55 million and ranging from small collaborative efforts with academia to larger efforts at the various space shuttle element locations across the country.

Two examples of successful projects include work platform redesign and glass bead process automation.

Work platform redesign. The space shuttle orbiter has two orbiter maneuvering system pods that use hydrazine as a propellant for maneuvering the Orbiter in space. The use of hydrazine requires extensive ground processing operations due to its hazardous properties. The pods are processed at the Hazardous Maintenance Facility at Kennedy Space Center, which has work platforms for access on various levels. Access to the 35-foot level platforms was laborious. Setting up the necessary scaffolding required a specially trained crew of six to eight technicians working two to three shifts, for example.

Technicians and engineers had been searching for a suitable solution for improved access. In 2002, IES was approached to fund a virtual reality simulation study that modeled the potential platforms. The IES program funded the project to build and install the platform hardware. With platform construction completed, access to the pod locations has been significantly improved, and resulting safety risks have been mitigated:

- Elimination of tool fall hazard by including tool holders integrated into the platforms.
- Elimination of technician fall hazard by the installation of standard handrails on the 27-foot level to replace chains and posts. Additionally, permanent handrails are designed so that removal during platform retraction is not required.
- Improved ergonomics, with the platforms at an elevation of 33 feet, 5 inches, improves technician access to the pod's thermal protection.
- Elimination of technician safety harness requirement during deployment, retraction, or use of the platform.
- Improved access and egress from the 27-foot level platforms, since scaffold set up to support the 35-foot level on the 27-foot level platforms is no longer needed (Figure 2).

Process efficiency has also been improved. One technician can now deploy or retract the platform in approximately 20 to 30 min-

A MORE SECURE PLATFORM

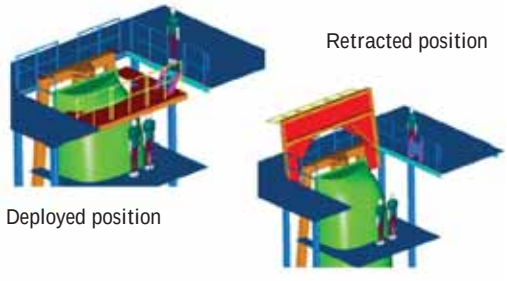


Figure 2. In one IES project, the work platform of the Space Shuttle Orbiter's maneuvering system pods were redesigned.

MULTIMEDIA ESTEEM

To highlight its activities, IES produced a video in 2002 in association with Texas-based Fusion Productions to catalogue a few projects that increased safety while reducing risk to the space shuttle program. The video was well received at NASA and earned accolades at the annual Telly awards, which showcase the best work of the most respected advertising agencies, production companies, television stations, cable operators, and corporate video departments in the world. With more than 10,000 entries, awards are handed out in three categories: multimedia, safety, and employee communication. In 2003, the IES production "Think about It" by Fusion Productions took first place in the multimedia category.

GAINS AND LOSSES

Even though the Space Shuttle Discovery landed safely in August, concerns over its launch several weeks earlier have caused NASA to suspend further launches until November. DeHavilland Information Services reported that investigators hope to determine why debris fell from the shuttle during its July 26 launch.

At least five pieces of insulation foam broke off during Discovery's launch — the largest weighing just under one pound; however, none of the debris hit the shuttle.

Source: DeHavilland Information Services

The glass beading process before the IES improvement project. Here, the technician is manually glass beading a section of the reusable solid rocket motor.

utes, saving an enormous amount of time. Additionally, these platforms eliminate the need for the old system of scaffold and picboards, resulting in time savings along with reduced risk to flight hardware and personnel. Technicians, many of whom have worked on this scaffolding for years, expressed a great deal of appreciation that their proposal for safety and process improvements had finally become a reality.

Glass bead project. Reuse of the reusable solid rocket motor (RSRM) usually requires a complete refurbish of the RSRM flight hardware. The robotic glass bead project took place at prime RSRM contractor ATK-Thiokol in Utah. Glass beading a surface is analogous to sandblasting it using glass pellets as the agent for removing material (paint, corrosion, and others) from a surface.

This project eliminated the inherently unsafe manual glass beading processes for both the work force and the hardware by replacing manual operations with a robotic process. This safety upgrade installed robotic systems that currently perform glass bead operations on case, nozzle, and igniter sections of flight hardware, as well as support equipment and railcar decks. This automated system replaces six manual abrasive blast stations and one semi-automated station. Prior to this project, all bare metal components at the facility were manually glass beaded except case cylinder membranes. By automating the glass beading process, the operator has been removed from the booth and put into the control room, thus eliminating the hazards that include the following:

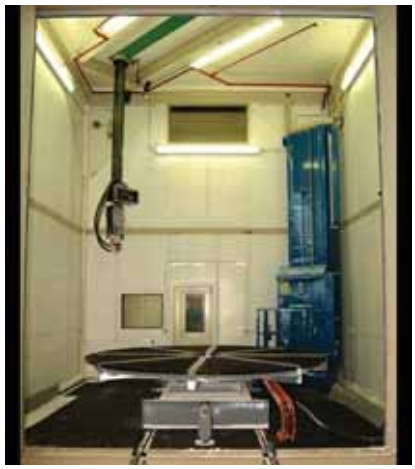
- Working directly with high pressure equipment and controlling surging lines
- Poor visibility inside the booth and for surveillance personnel
- Working in high noise areas
- Trip, fall, and pinch points
- Awkward positioning in small work areas

As a consequence, the hardware risks eliminated include variability in standoff distances and operator technique, poor repeatability with manual operations, and excessive erosion on hardware caused by inadvertent dwell or standoff variances.

The improvements have positively impacted employee morale. Glass beading technicians who previously expressed concern about being able to perform their job adequately into the future now feel that they can easily see working in this job until retirement.

Conclusion

The IES program has provided the space shuttle program work force an avenue to bring forward potential projects that improve safety of the flight hardware, the people that work on it, and even the general public. It advocates and funds low-cost, quick-turnaround projects that are high in value with a focus on improving safety.



After the IES project, glass beading was automated.

IES also plays a significant role in helping improve employee morale by providing an opportunity to the space shuttle work force to develop innovative solutions to the issues they face during their daily jobs.

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