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Shuttle Safety Improvements

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SPACE SHUTTLE SAFETY IMPROVEMENTS

The Space Shuttle has been flying for over 20 years and based on the Orbiter design life of 100 missions it should be capable of flying at least 20 years more- if we take care of it. The Space Shuttle Development Office established in 1997 has identified those upgrades needed to keep the Shuttle flying safely and efficiently until a new reusable launch vehicle (RLV) is available to meet the agency commitments and goals for human access to space. The upgrade requirements shown in figure 1 are to meet the program goals, support HEDS and next generation space transportation goals while protecting the country's investment in the Space Shuttle. A major review of the shuttle hardware and processes was conducted in 1999 which identified key shuttle safety improvement priorities, as well as other system upgrades needed to reliably continue to support the shuttle missions well into the second decade of this century. The high priority safety upgrades selected for development and study will be addressed in this paper.

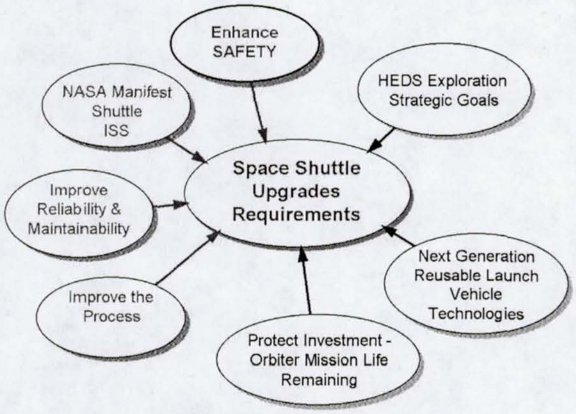


Figure1. Why Space Shuttle Upgrades?

A major shuttle program activity has been in developing a probabilistic risk analysis (PRA) tool that can quantify shuttle risk and be used to identify potential upgrades based on reducing that risk. Shuttle probabilistic risk models quantify the potential for loss of vehicle and crew due to catastrophic system failures. Those models are developed at the component, system, and hardware element level and this provides NASA with a method for ranking hardware risks. More importantly this methodology provides a way to assess the potential risk reduction impact of a suite of proposed safety upgrades. As an example Figure 2 illustrates the significant reduction in the loss of vehicle (LOV) risk during ascent which has been achieved by modifications to the Space Shuttle Main Engine (SSME), and which could be improved with proposed future upgrades. The result of an analysis of the risk reduction effects of several proposed safety upgrades is illustrated in Figure 3. The current estimate of ascent catastrophic risk is approximately 1 in 483 missions, which could be reduced to almost 1 in 1000 missions if we were to successfully implement all the high priority safety upgrade candidates identified.

The identified candidate safety upgrades were prioritized based on their flight safety benefit. Potential reduction in LOV risk probabilities was the primary basis for selecting the safety upgrades, with the exception of the cockpit avionics upgrade (CAU). The CAU was selected as the highest priority safety upgrade based on the potential for making major improvements in situational awareness for the flight crew during highly critical multi-failure flight scenarios.

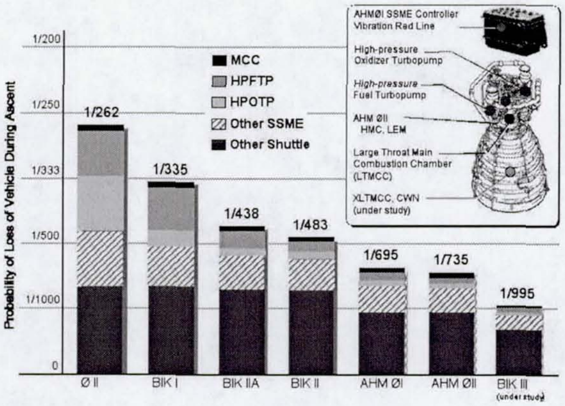


Figure 2. SSME Upgrades Reduce Ascent Risk

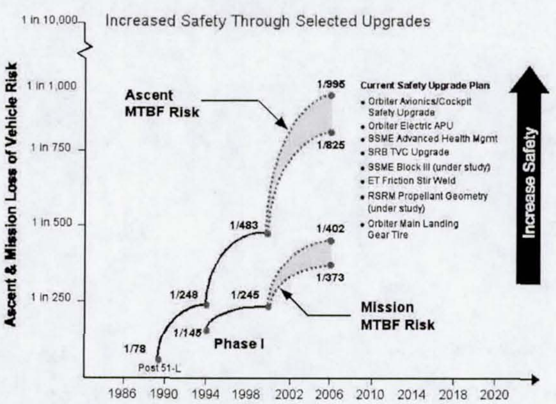


Figure 3. Safety Benefits of Proposed Upgrades

CAU is described on figure 4. This upgrade takes advantage of the new glass cockpit already implemented in two of the four orbiters, and which is scheduled for the other two during planned modification periods over the next couple years. The CAU will add the capability to display additional information on the new glass cockpit flat panel display screens. The improved cockpit display suite and computational platform will have on-board shuttle abort flight management software for real-time abort advisories and enhanced caution and warning system for improved on-board failure diagnostics.

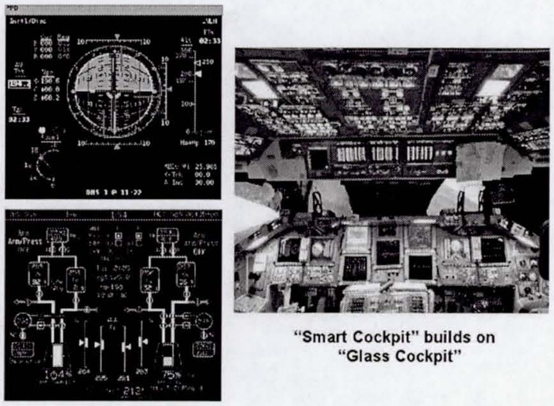


Figure 4. Cockpit Avionics Upgrades

The electronic auxiliary power unit (EAPU), shown in figure 5, is another high priority upgrade which would significantly reduce the mission risk. This upgrade replaces the hydrazine driven gas turbine that supports the orbiters hydraulic system with a battery driven electric motor. The safety benefits for this upgrade are two fold, first it gets rid of the toxic, flammable, corrosive hydrazine and second it replaces a 35000-RPM gas turbine with an electric motor. The electric motor that drives the hydraulic pump will provide an output to the hydraulic system that will be transparent to today's system to avoid recertification of the control system. In addition to the flight safety benefits significant ground safety benefits will be achieved from eliminating hydrazine handling and processing.

A major reduction in SSME risk is planned by the introduction of a highly sophisticated use of digital technology to carry-out onboard real time assessment of failure modes which are not currently detectable by onboard computers. There are two phases of SSME advanced health management system upgrades figure 6. The first phase is in development and adds the necessary modifications to the SSME controller to facilitate the addition of a new vibration redline.

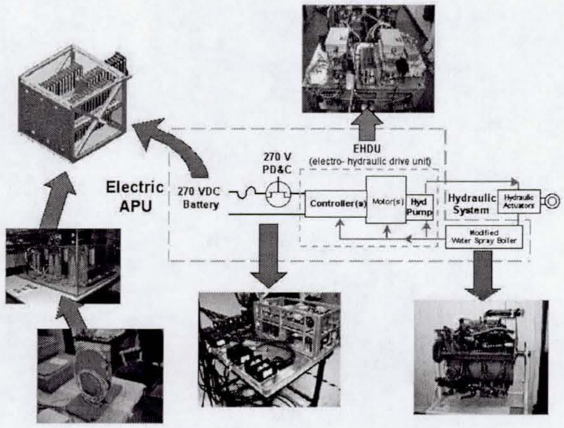


Figure 5. Electric Auxiliary Power Unit (EAPU)

The use of this new redline is projected to eliminate enough of the castrophic failures to reduce the risk for engine loss by 23 percent. The second phase still in formulation will provide a health management computer. This computer will provide expanded vibration monitoring capability, operate the linear engine model and store pertinent engine flight data for post flight assessment. This added information can be used to shut down, throttle or make a performance correction to avoid a castrophic loss of the engine. This would reduce the risk for engine loss by additional 21 percent.

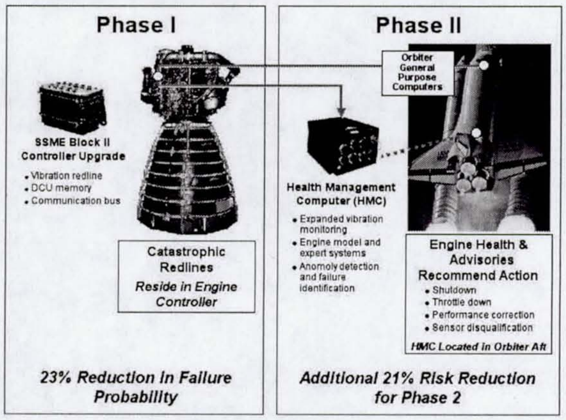


Figure 6. Advanced Health Management System

Similar to the orbiter's EAPU upgrade strategy there is a planned upgrade for the SRB Thrust Vector Control (TVC) APU to eliminate use of hydrazine. However, the SRB upgrade will use a helium driven APU instead of the batteries planned for the orbiter. This upgrade shown on figure 7, utilizes most of the existing TVC system but adds helium tanks (3), an isolation valve and regulator and modifies the turbine and the controller required for replacing hydrazine with helium. The safety benefits mostly associated with getting rid of the hydrazine reduces the over all risk of the SRB by 21 percent.

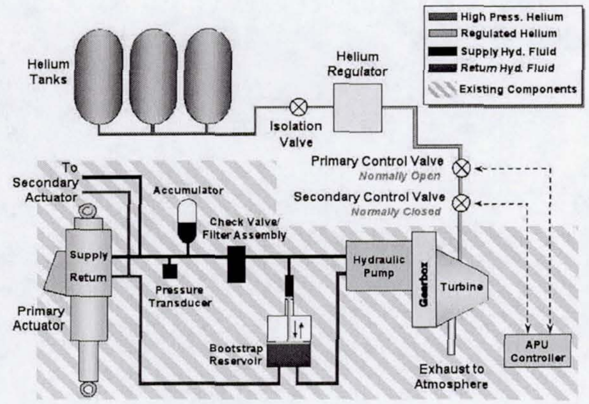
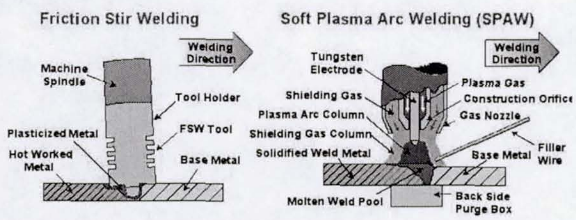


Figure 7. SRBTVC Helium Powered APU

A change to the shuttle's external tank (ET) welding process adds a friction stir welding (FSW) capability for manufacturing the longitudinal LOX and LH2 barrels. Applying the FSW technology adds weld joint strength, margins, fracture toughness and process control. It will improve the weld process bandwith parameters toward the goal of a 6 sigma control process. It's primary safety attribute will be a significant reduction in weld errors while decreasing ET production time and cost. A comparison of the new FSW process to the existing fusion soft plastic arc welding is shown on figure 8. FSW provides a major reduction in weld set up and will vastly reduce and simplify the process parameters.



	FSW	Fusion	
Weld Set Up	Schedule Selection Pin Tool Selection	Schedule Selection Shield Cup Design Orifice Size	Tungsten Position Tungsten Size/Type Wire Alloy and Diameter
During Welding	Plunge Depth/load Rotation Speed Speed Travel Centerline Position Length (Tapers)	Current Shield Travel Speed Wire Feed Rate APC/AVC Reverse Current Plasma Gas	Gas and Flow Side Purge Gas and Flow Pulse Frequency/Duty Cycle Arc Gap Oscillator Width (Cover Pass) Oscillator Dwell (Cover Pass) Oscillator Speed (Cover Pass)

Friction Stir Welding Vastly Reduces and Simplifies Process Variables

Figure 8. Friction Stir Weld Process Comparison

The main landing gear tire is being redesigned to increase the tire load capacity, thereby adding safety margin for landing. This upgrade shown on figure 9 will modify and add tire plies. The new tire designs are currently in testing and proceeding toward a decision for implementation in the fall.

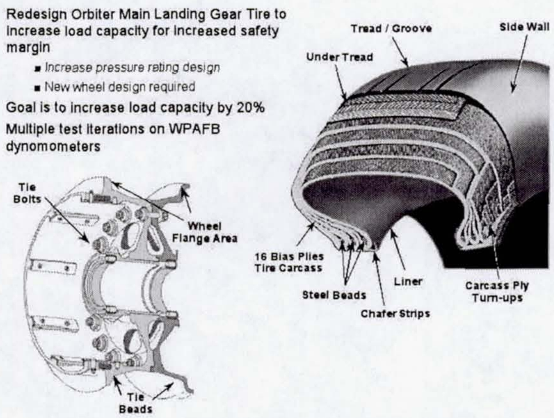


Figure 9. Improved Main Landing Gear Tire

The goals for performing these upgrades are to achieve a major reduction in mission risks and reduce the probabilities for loss of vehicle for ascent, on-orbit and entry. That includes improve the crew cockpit situational awareness to manage critical operational situations. The challenge is to implement these upgrades into the shuttle fleet in the 2005 to 2007 time frame without impacting the on-going manifest support.

The only upgrades that are currently approved for system development are the SSME AHMS phase 1 vibration redline and the ET friction stir welding. The CAU, EAPU, SSME AHMS Phase II, SRB TVC/APU and MLG Tire/Wheel upgrades are progressing in definition phase toward authority to proceed (ATP) reviews. In addition to these upgrades several studies are in work on abort improvements, thermal protection systems and ground SCAPE suits.