Shuttle Abort Flight Management (SAFM) – Application Overview

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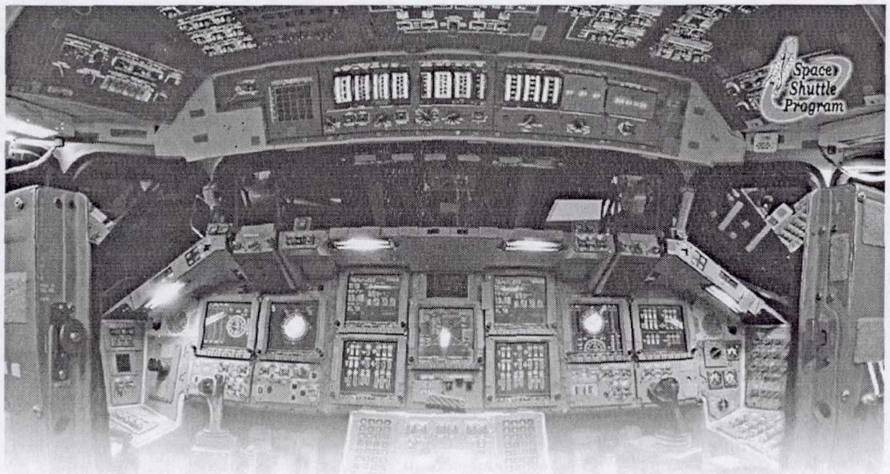
One of the most demanding tasks that must be performed by the Space Shuttle flight crew is the process of determining whether, when and where to abort the vehicle should engine or system failures occur during ascent or entry. Current Shuttle abort procedures involve paging through complicated paper checklists to decide on the type of abort and where to abort. Additional checklists then lead the crew through a series of actions to execute the desired abort. This process is even more difficult and time consuming in the absence of ground communications since the ground flight controllers have the analysis tools and information that is currently not available in the Shuttle cockpit.

Crew workload specifically abort procedures will be greatly simplified with the implementation of the Space Shuttle Cockpit Avionics Upgrade (CAU) project. The intent of CAU is to maximize crew situational awareness and reduce flight workload thru enhanced controls and displays, and onboard abort assessment and determination capability. SAFM was developed to help satisfy the CAU objectives by providing the crew with dynamic information about the capability of the vehicle to perform a variety of abort options during ascent and entry.

This paper presents an overview of the SAFM application. As shown in Figure 1, SAFM processes the vehicle navigation state and other guidance information to provide the CAU displays with evaluations of abort options, as well as landing site recommendations. This is accomplished by three main SAFM components: the Sequencer Executive, the Powered Flight Function, and the Glided Flight Function.

The Sequencer Executive dispatches the Powered and Glided Flight Functions to evaluate the vehicle's capability to execute the current mission (or current abort), as well as more than 18 hypothetical abort options or scenarios. Scenarios are sequenced and evaluated throughout powered and glided flight. Abort scenarios evaluated include Abort to Orbit (ATO), Transatlantic Abort Landing (TAL), East Coast Abort Landing (ECAL) and Return to Launch Site (RTLS). Sequential and simultaneous engine failures are assessed and landing footprint information is provided during actual entry scenarios as well as hypothetical "loss of thrust now" scenarios during ascent.

The Powered Flight Function determines vehicle performance achieved at the target Space Shuttle Main Engine (SSME) shutdown position and velocity conditions associated with the various abort options. This is accomplished by a predictor-corrector guidance technique whose final iteration is used to determine a hypothetical main engine cut off (MECO) condition for each candidate abort target. The MECO state for each hypothetical scenario is evaluated to determine whether the vehicle may execute that abort option. The information from all the hypothetical abort options is further processed to select the recommended abort option for single or dual engine failures. This is displayed to the crew on the Ascent Horizontal Situation Display. Powered Flight may also be dispatched to provide a loss-of-thrust condition to the Glided Flight Function for scenarios that require both powered and glided flight processing.



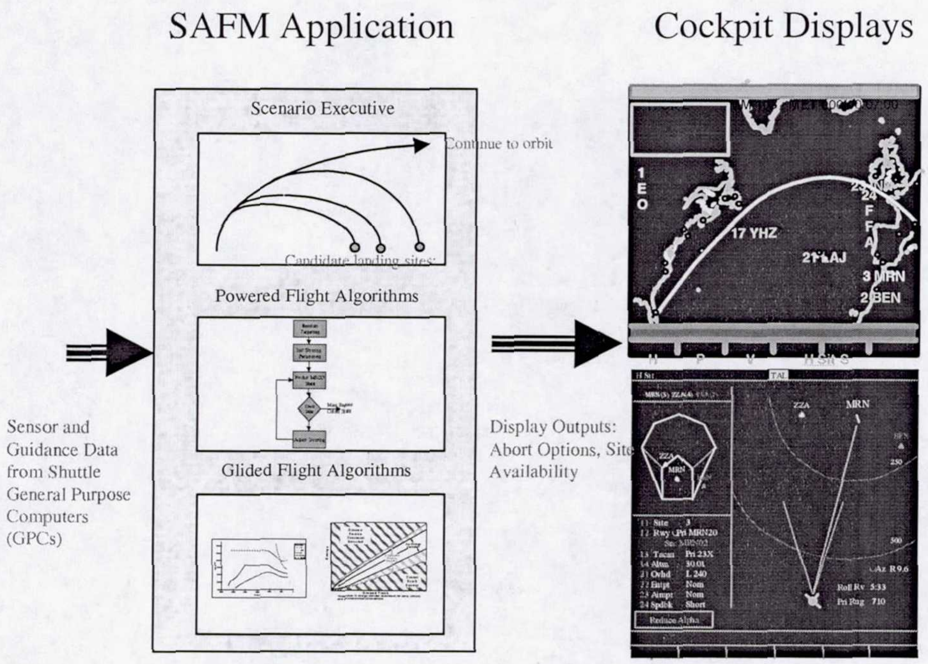


Figure 1. SAFM Application in Cockpit Avionics Upgrade.

The Glided Flight Function determines Shuttle glide capability and continuously updates assessments of candidate runways during powered ascent as well as glided flight. The Glided Flight algorithms propagate the current vehicle state to predict an atmospheric "pullout" state assuming a total loss of thrust from the main engines. Energy/range corridors are used to determine the vehicle footprint in range and crossrange based upon the predicted pullout state. Range and crossrange are adjusted for terminal geometry conditions, and energy is compensated for phugoid motion. Figures of merit for each candidate runway are assigned based upon the site's location in the footprint. Finally, candidate runways are prioritized according to figure of merit, and information about runway facilities. This information is displayed to the crew by coloring available landing sites on the ascent display, and by depicting candidate landing sites with respect to a range/crossrange footprint on the entry display.

This overview discusses each of these main components and the design decisions that were made in developing them. Background information is also provided on the types of Shuttle aborts, as well as on Shuttle guidance algorithms as they apply to abort processing. An overview of Powered and Glided algorithm validation results is presented as well. Finally, the layout and description of the dynamic SAFM data on the new CAU flight displays are covered.