Plan, Train, and Fly:

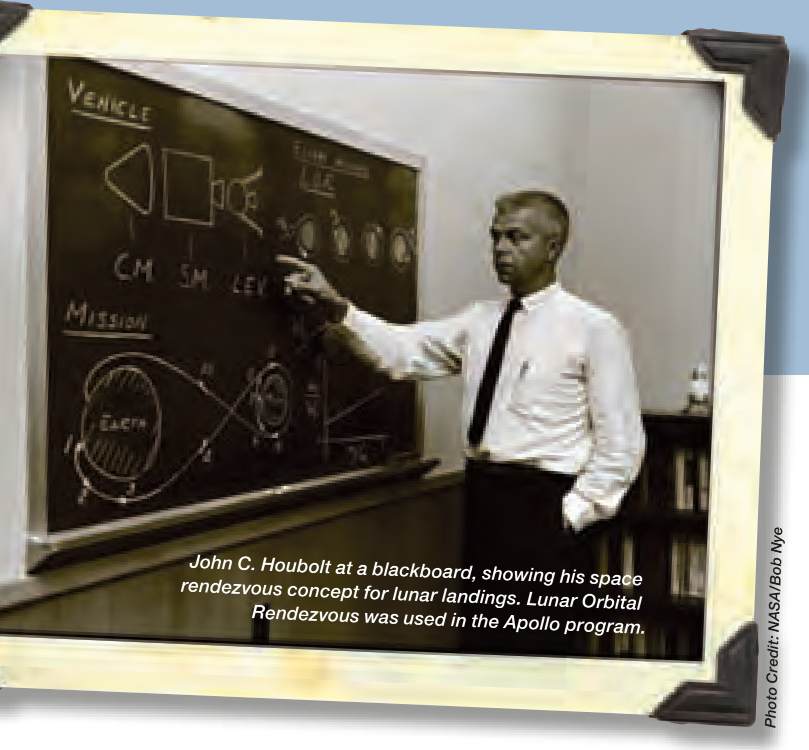
MISSION OPERATIONS FROM APOLLO TO SHUTTLE

BY JOHN O'NEILL

Personnel at the Mission Operations Directorate at the Johnson Space Center are the final integrators of the planning and execution steps that must occur to get from mission definition and design to flight. Over the years, the technology of some of this essential work has changed, but the general principles and the dedication and skill of those doing it remain the same. A brief look at the history of planning, training, and flying—the three related functions within human space flight mission operations—will make some of the challenges clear and show how we met them in the past and how we meet them today.

On NASA Kennedy Space Center's Shuttle Landing Facility, the Shuttle Training Aircraft (STA) takes to the skies. The STA is a Grumman American Aviation–built Gulf Stream II jet that was modified to simulate an orbiter's cockpit, motion and visual cues, and handling qualities. In flight, the STA duplicates the orbiter's atmospheric descent trajectory from approximately 35,000 ft. altitude to landing on a runway. Because the orbiter is unpowered during reentry and landing, its high-speed glide must be perfectly executed the first time.

Photo Credit: NASA



John C. Houbolt at a blackboard, showing his space rendezvous concept for lunar landings. Lunar Orbital Rendezvous was used in the Apollo program.

Photo Credit: NASA/Bob Nye

Planning

President Eisenhower once said, "It has been my experience in a really great crisis that plans were useless but that planning was indispensable." That is a good guiding principle for the contingency planning that always goes into NASA missions, but, in the complex environment of space, rigorous planning is equally indispensable in accomplishing the defined mission objectives.

Once mission requirements and spacecraft capabilities are in hand, planning essentially begins with the trajectory, navigation, and guidance design. Consider the challenges faced by the Apollo trajectory planners. Activities associated with trajectory control were the largest part of the operational overhead on every Apollo mission. In key mission phases, trajectory control took priority over all other activity and drove the timeline. The trajectory was the framework or skeleton for all subsequent plans and procedures. Before the first moon flights, engineering, trajectory, science, and operations personnel collaborated to develop Design Reference Missions to give "best estimate" guidance to the Apollo mission designers. The Gemini program and its rendezvous missions provided a key source of data that the planners needed to design accurate lunar trajectories.

The flight-planning effort also included developing and refining crew procedures. The flight plan itself was and still is a precise sequence of the interrelated crew and ground support activities. This operations documentation shapes the training that familiarizes crew and controllers with mission procedures and contingencies.

Flight crews also wanted "cue cards"—irregularly shaped cards that fit in available panel space in the crew station—to summarize critical procedures for ready reference. The Apollo 8 ascent cue cards provided an extra bit of excitement in the final launch preparations. The backup crew installed the cards during the last hours of the count so they would be in place for the prime crew. This meant placing the cards with their Velcro backing in position on the mating Velcro on the panel spaces. At that time, sticky-back Velcro was not yet available; when the cue cards were finalized, an adhesive was used to attach the specially shaped Velcro to the cards. Soon after the backup crew completed the installation, a pad technician discovered that the cards were falling like leaves. The adhesive had failed. In a panic procedure in the Operations and Checkout Building at Kennedy Space Center, the old adhesive was scraped off and fresh adhesive applied. The process took most of the night but was finished in time.

Apollo 11 obviously presented significant new challenges and produced many productive changes. Coordination between the crew and ground support was extremely critical in a mission that included lunar landing and a lunar orbit rendezvous. During the two months before flight, approximately 1,100 changes were made to the flight plan and crew checklists. All those changes were vetted by the crew, the flight controllers, and NASA and contractor engineering personnel. Doing that required streamlined and improved information exchange and led to the development of a formal configuration control process similar to that used for hardware and software today.

Consider the technology of the Apollo era for a moment. Much has been written about the limited capacity of the spacecraft and mission control computers. The lack of word processors also made the careful and accurate updating of operations documentation very tedious. And there were none of the tracking and data relay satellites to provide the full communication coverage that the Space Shuttle and International Space Station enjoy today, and no GPS for navigation support.

Those were the limits on communications resources when the entire operations and engineering force mobilized to deal with the Apollo 13 emergency. As the onboard procedures were reworked, reassembled, and modified, the extensive directions from Mission Control to the crew had to be transmitted totally over the air-to-ground voice loops. This included the famous step-by-step instructions for using tape and covers from the flight plan to adapt a command module lithium hydroxide canister for lunar module use.

Planning, reviewing, and carefully revising the plans have been the cornerstone of NASA's mission success. Operations planning must start during the requirements phase of a program and be an integral part of the design, development, and testing phases. Two of the most important questions are, "Can the systems be operated in a normal and contingency mode that