THIS IS NOT JUST ANOTHER SYSTEM UPGRADE: MISSION CONTROL – CREW COMMUNICATIONS DURING ROUTINE AND NON-ROUTINE EVENTS IN SHUTTLE AND STATION OPERATIONS

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The current technological and organizational configuration of the Mission Control Center (MCC) at Johnson Space Center (JSC) has been a mainstay of NASA's approach to human space flight. MCC represents a unique combination of traditional command and control approaches to supervisory control, and a set of highly experienced, team-based coordinated experts conducting distributed supervisory coordination of short-term space flight missions. As NASA moves into a new era of Human Exploration and Development of Space (HEDS), the mission control functionality of JSC will be required to change substantially to enable extended exploration missions to perform successfully.

The evolution of MCC has combined modest technological progress (compared to changes in the non-NASA technology environment) with an increasing demand on flight controllers to learn, integrate, and respond to changes in increasingly complex vehicles, mission profiles, and system constraints. The current Flight Control Room (FCR) configuration of frontroom and backroom controller teams represents the culmination of nearly 40 years of experience with mission-oriented, launch-to-landing space flight operations. The STS program alone has over 100 flights and thousands of simulation exercises of experience in coordinated mission control activity. Research conducted by grants NAG 9-1008 / 1292 during mission simulations has begun to quantify the differences in controller communication activity and use of voice channel bandwidth between phases of flight. Preliminary results focusing on STS FCR operations indicate that task loads and perceived time pressure experienced by controllers during ascent and entry phases are significantly higher than those experienced during orbital operations. However, the use of voice communications channels during ascent and entry seem to represent less overall bandwidth use characteristic of "burst rate" transmissions. Controller-crew communication is focused on knowledge and task synchronization, selection among known procedures, and rapid determination of status and response.

On-orbit FCR communications collected indicate a wider range of task demands, coordination needs, and time pressures. Serendipitous new research questions have emerged in the grant activity, now that the Space Station (ISS) has continuous habitation by expedition crews. (Original project schedules would have resulted in an ending of data collection before the launch of the Expedition One crew.) The grant now has the unprecedented capability to begin investigations of FCR communications in a non-mission (continuous operations) configuration, as well as inter-FCR coordination demands. ISS FCR communication activity has highlighted several critical issues involving both technological and organizational challenges to traditional MCC operations. Emergency response and malfunction procedure coordination between MCC and crew is in an early phase of development, operational verification, and testing not seen since the beginning of the STS program 20 years ago. ISS represents a new organizational challenge to MCC, rather than simply a technical challenge, in two distinct ways. Although the STS vehicle was technologically very different from all previous vehicles, the organizational experience of launch-to-landing mission control and short-term mission profiles continued through STS. In addition, the continuous operations of ISS require a different philosophy of developing and integrating experience in a real-time environment. Traditionally, multiple simulation hours are logged per hour of live mission operation, with associated development and debugging of procedures and communications practices in preparation for a specific mission. This ratio is reversed in the ISS environment.

Bandwidth utilization for procedure verification and MCC-crew coordination in the ISS FCR is critically different from bandwidth utilization for STS operations. Both technological limitations (limited capability for exchanging electronic procedures) and operational inexperience (novel requirements for integrating console position information and crew member interaction with physically distributed vehicle resources) indicate distinct demands for future information technology systems and coordination practices using voice channel communications. Preliminary, qualitative evaluations of voice communications activity suggest that on-orbit coordination in early mission phase activities requires substantially more high duty cycle bandwidth utilization, rather than the burst-rate utilization characteristic of well-established processes in ascent and entry phases of flight. These preliminary findings require new analytical capabilities and an extension of metrics and methods from traditional signal processing and communications engineering, to appropriately describe the bandwidth management and information coordination demands of coordination within and between FCR controller teams and one or more crews.

The transition to HEDS mission profiles highlights an additional challenge to MCC technological and organizational experience: the effect of information transmission delays. Exploration missions to Mars would result in one-way communications delays of as much as 1000 seconds, three orders of magnitude greater than the maximum effective delay for active, continuous human supervisory control. Controllers are not always aware of the command delays (on the order of six seconds for command receipt, verification, and execution) that affect STS and ISS systems in different ways. Thermal, life support, and other long time-constant systems have more uncertain feedback cycles associated with command activity, as compared to electrical and propulsion systems. Information sharing to provide effective coordination that is robust to transmission delays is in an extremely immature level of development. Interface designs, cognitive supports, and data flow technologies will all have to be substantially revised in order to provide the necessary levels of coordination and knowledge exchange between ground-based controllers and on-board crew. Substantially increased MCC functionality will be required to be placed on the exploration vehicle, with improved capability for MCC-crew interactions to take place locally between on-board systems and crew members. An initial model for these new functions is represented in the recent implementation of reduced continuous staffing FCR consoles and greater capability for distributed controllers to interact with MCC functions beyond the physical boundaries of the FCR. These changes highlight the issues of delayed response to information exchanged between FCR consoles and on-board systems; delays associated with status evaluation, response formulation, and response coordination for novel situations and unique mission configurations; and data exchange demands for historical trending and projection of current system states into the future. It is hoped that the results of the current data analysis will fulfill the original goals of the grant: learn from STS experience, inform ISS evolution, and design HEDS system functions.