Enhanced ISS Robotic Ground Control

Phillip Callen/ER3
Software, Robotics & Simulation Division
281-483-8087
phillip.s.callen@nasa.gov

Problem Statement

- **The ISS is moving to as much ground control for robotics as possible in order to free up crew time (SPDM ops are 100% GC)**
- **Performing robotic operations on ISS is a time consuming process (1-3 days)**
- **Because planning for robotics operations is a constraint driven process, there are few windows (1-3 days) available**
- **This limitation of available windows is in conflict with our desire and need for an increasing number of robotic operations**

Objective

- **The objective of this effort is to increase the efficiency of ISS ground-controlled robotics operations**

- **Use a phased approach to steadily increase the necessary system infrastructure and increase confidence in the system in a fashion similar to how ground control was implemented**

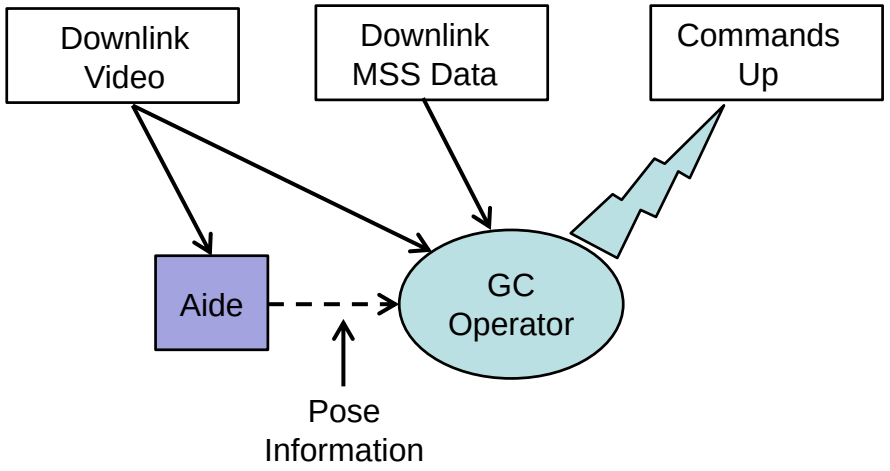
- **The successful outcome will provide a tremendous increase in robotics utilization for the life of ISS as well as provide the blueprint (and validation) for future exploration missions utilizing remote robotic operations**

Premise

- **The MSS is existing hardware and software that is not easy to modify (both from a cost and technical perspective)**
- **Intelligent ground control aids can be developed to improve and increase efficiencies for the GC operator**
- **The primary sensor that is available to provide information and help close the loop is video**

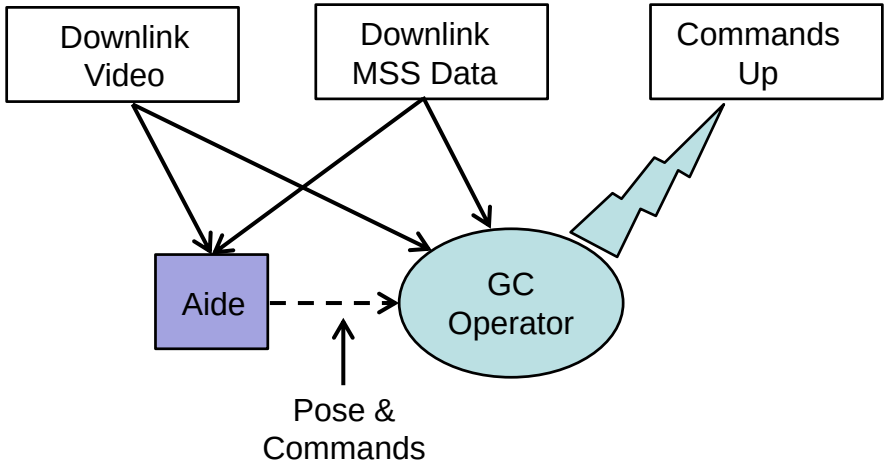
Development Phases

- **Phase 1 – Initial Aide Identification and Development**
  - **Joint development effort with ER and DX**
  - **Aide would provide additional/enhanced information to the operator, like digital pose estimation based on Natural Feature Image Recognition (NFIR)**
    - **Starting with one of the most time-consuming and most frequent ground operations – SPDM grasp of hardware fixtures**
  - **Initial implementation would be a standalone box, i.e. something that can be taken to a simulator or MCC and just plug a video feed into it.**



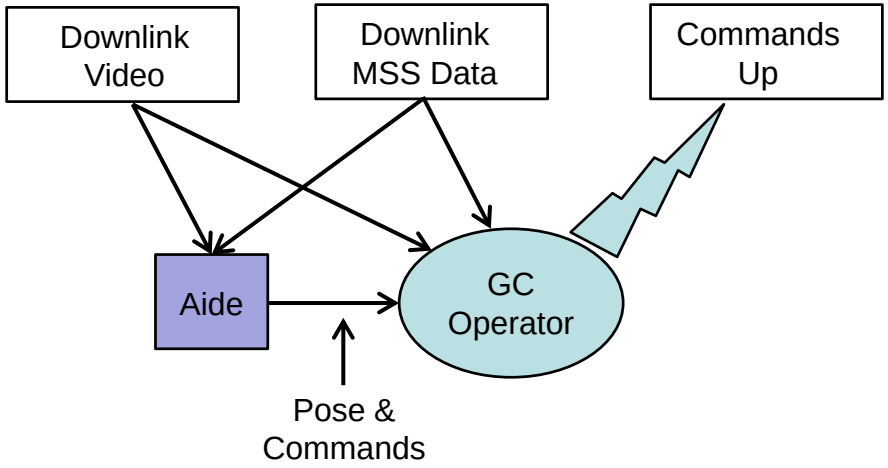
Development Phases (cont.)

- **Phase 2 – Increased Aide Functionality**
  - **Aide could suggest MSS commands or perhaps even go so far as generate the commands, but not send them.**
  - **Begin fusing data from various camera views and MSS system data (i.e., control modes, joint position, etc.)**
  - **Ground retains full control over what commands get sent onboard**



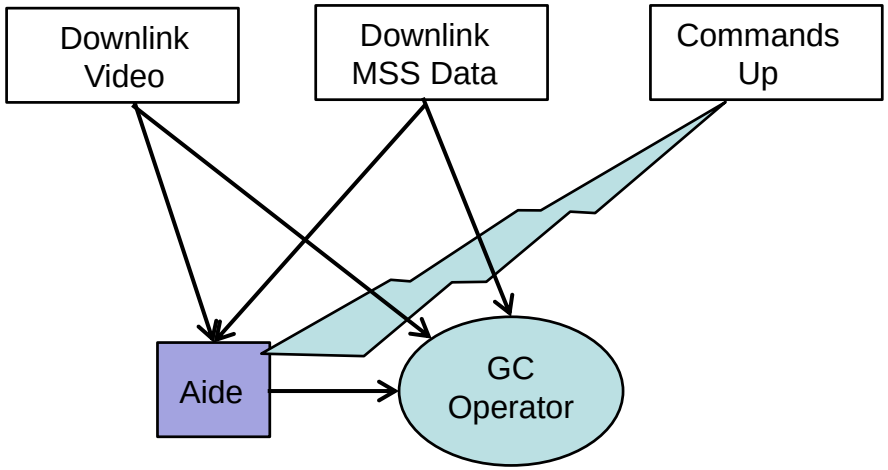
Development Phases (cont.)

- **Phase 3 – Limited Autonomy**
  - **Aide generates and sends a subset of MSS commands perhaps limited to only non-motion commands or motion commands limited by distance to structure and TDRS coverage**
  - **More mature and increased data fusion capability**
  - **Ground still does "close quarters" commanding, and would still have the responsibility to monitor and be prepared to safe the system if necessary**



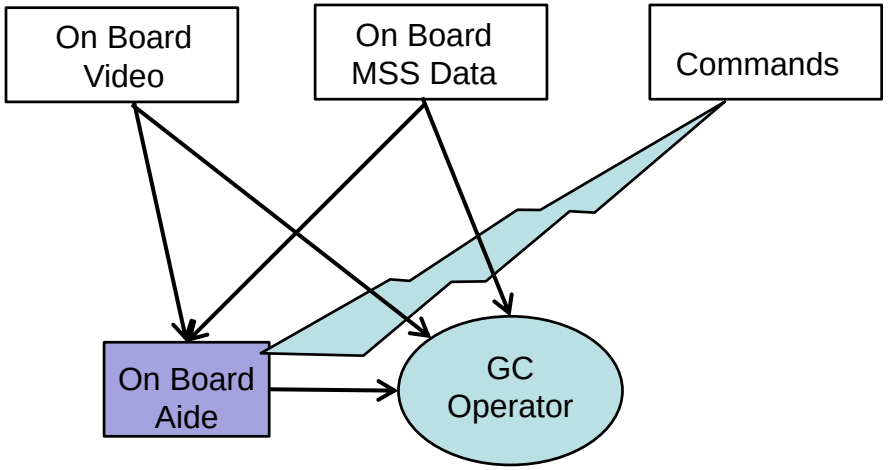
Development Phases (cont.)

- **Phase 4 – Full Autonomy**
  - **Aide generates and sends all MSS commands regardless of motion distance and operational complexity**
    - **No motion during Ku-band or S-band LOS**
  - **Full maturity and intelligence of data fusion capability**
  - **Ground would still monitor and would still be able to safe the system if necessary**



Development Phases (cont.)

- **Phase 5 – Full Autonomy (On-Board ISS)**
  - **Aide generates and sends all MSS commands regardless of TDRS coverage**
    - **Stand-alone software would be needed onboard to continue during LOS periods (may require sub-phases to get to full implementation)**
    - **No changes to MSS software**
  - **Ground would still monitor when not LOS and would still be able to safe the system if necessary**

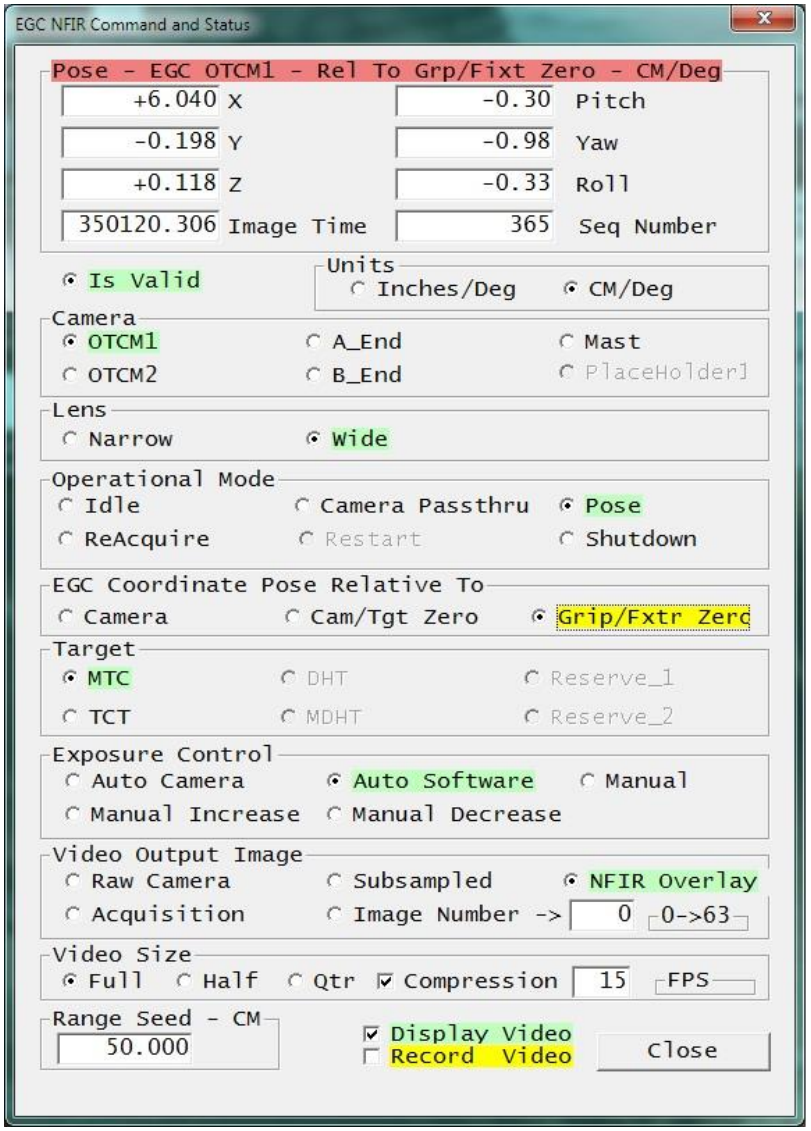


Current Status

- **ER and MOD awarded funds for Phase 1 through the JSC IR&D for proof-of-concept development**

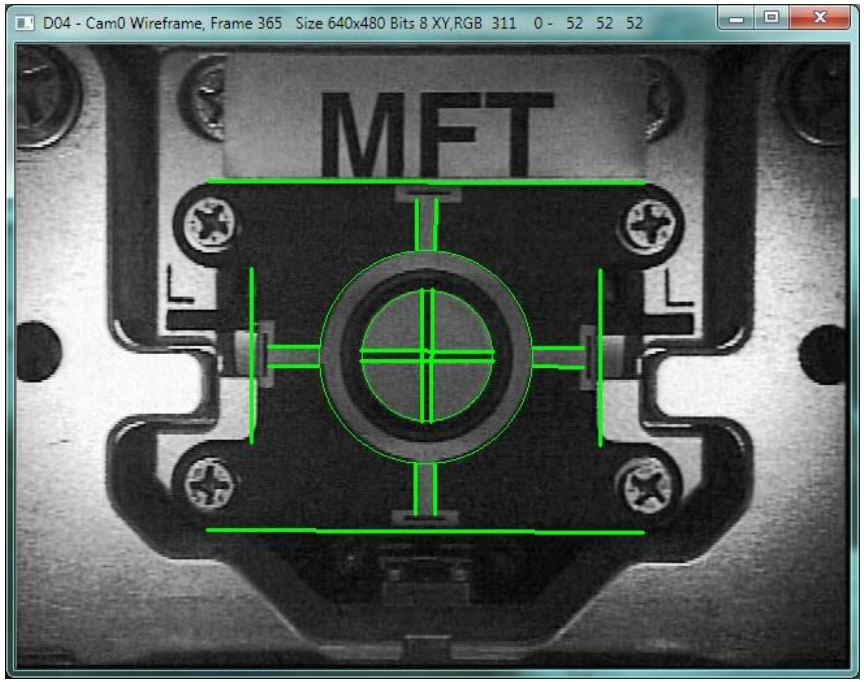
- **ER developed NFIR capability based around MTC target and grasp operation using video from recent grasp operations**
  - **Initial results showed that the concept works as desired and that continued development is worthwhile**
  - **A real-time test in the MCC was done in June had very encouraging results**

Enhanced Ground Control Demo



User interface showing alignment positional error

Green overlay provides visual feedback of tracking



Forward Work

- **Solution is being refined based on data collected during the real-time test in June**
- **Work is starting on porting from Windows to Linux (MOD requirements in order to use the software in MCC)**
- **Procuring MCC compatable frame-grabbing and processing hardware**
- **Planning to expand the number of grasp target types supported**
  - **Only MTC target is in the database now – this is the most prominent target type and will be the "standard" target for all future hardware**
- **Planning to expand capability to support operations beyond grasps like RPCM insertion and FRAM installs.**
  - **These are non-target based operations and will utilize surounding structure for the cueing information.**

Forward Work (cont.)

- **Based on positive performance shown to date, a CR will be submitted for continued development of Phase 1 and Phase 2**
  - **Phase 1 activity would be an expansion of operations that can be used by ground control**
    - **Additional grasp targets**
    - **Non-grasp operations like FRAM installs and ORU insertions**
  - **Phase 2 would begin the building of a commanding capability fusing data from cameras and MSS data**
  - **Targeting demonstration for SpaceX-6 – 3 FRAMs up/3 FRAMs down**
- **Subsequent CRs would be submitted for the remaining Phases based upon the success of the proceeding Phase**