

A Look Over the Horizon

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Purpose

- In the past, high launch and satellite development costs coupled with long satellite development schedules caused the space community to be “risk adverse” to change
- The costs to space have been decreasing dramatically over time which **should** allow a shift to becoming more “risk tolerant”
- The acceptance of risk opens new possibilities for future systems in the areas of:
 - *Acquisition*
 - *Space/Ground Link*
 - *Satellite Control System*
 - *Operations*
- Possibilities presented are based on cutting edge current technology – no new technical innovation required
- Innovation can be achieved by current systems via evolution

Lower costs to entry into space should allow the community to be more “risk tolerant” to change



Possibilities for Future Ground Systems

Acquisition

- Ground functions bought like an App on iTunes or Google Play and put into a framework – much like a cell phone
 - *Would greatly help if telemetry and command satellite bus (data) standards were adopted & adhered to*
- System requirements/CONOPS are captured in a robust test plan and procedure that is developed very early in the program
 - *Defines requirements and CONOPS in an unambiguous form*
 - Passing the test in the relevant environment means the system will be accepted
 - Test can be tweaked as needed by SPO or developer by mutual agreement
 - *Test will follow system throughout its lifecycle*
 - Test escapes will result in changes to the test to prevent future occurrences
 - System changes/enhancements will be captured in the test
- For fleets/enterprises, the realization there is no “endstate” for the system
 - *Systems will be constantly evolving to adopt new technology and respond to new threats*
 - *Work packages should be partitioned to be short-term, focused efforts*

Need to identify acquisition processes to accommodate long term missions/infrastructure that are constantly evolving



Possibilities for Future Ground Systems

Space/Ground Link

- Sufficient satellite contact resources to allow contact on demand as opposed to contact by schedule
 - *Stop building mission specific antennas & transform existing antenna sites to become multi-use*
 - *Use commercial antenna assets where appropriate*
- Higher speed mission data disseminated via RF to IP devices then over commercial or protected comms – no need for on-site decommutation
- Satellite link formats become CCSDS compliant
 - *Commercial standard – no special custom equipment required*
 - *Packetized and self routing*

Scheduling becomes whenever needed by a program almost anywhere in orbit



Possibilities for Future Ground Systems

Satellite Control System

- Location is irrelevant to function
 - *Anything (mission data processing, satellite operations, etc.) can be done from anywhere with authorized network connectivity to processing elements and antenna resources*
 - *Resiliency backup can be anywhere there is authorized connectivity*
 - Not even required to have all operators on the same floor in an emergency
- With appropriate cyber protections, possibly hundreds of virtual containers (or more) performing the same function anywhere within a cloud or fog environment
 - *Could leverage commercial cloud providers for many functions anywhere in the world*
 - *Encrypt and decrypt within containers*
 - *Opens new paradigms for system reliability and resiliency*
 - *If mission data processing is able to occur in the cloud close to the ground terminal it could greatly reduce long haul communication need for that program*



Possibilities for Future Ground Systems Operations

- Implement “Machine Learning” in ground systems to reduce operator workload and error
 - *When out of limits are detected the system captures the telemetry signature including the past few commands and associates the signature with an action (see Backup Slide for detail)*
 - *After accumulating experience, the system can ascertain its own status and readiness with a given degree of confidence which builds over time (system become “self-aware” of status and readiness and can report it)*
- “Common” operator presentation layer regardless of T&C system
 - *Data on all key satellite systems are accessed the same way and the layout, use of color and warnings are consistent across systems (common “look and feel”)*
 - *Will insulate operators from infrastructure changes that may be occurring at lower levels within the enterprise stack up to changing the underlying T&C product*
 - *With experience, operators could fly different missions with reduced training and possibility for error*
- Human interface with data may become voice and/or motion, virtual reality and perhaps someday, thought
- Satellite models could be run in parallel with operations to improve model fidelity
 - *Telemetry output of model would be compared to real life in a variety of real operational space environments – model differences would be adjudicated*
 - *Would allow spacecraft idiosyncrasies to be incorporated into the spacecraft model*
 - *Higher fidelity models not only benefit development, operations and troubleshooting but also any enterprise exercises involving the spacecraft model*

Reduced workload frees operators to perform other meaningful work



Possibilities for Future Space Systems

Satellites

- Use of network based protocols for communication between spacecraft components
 - *Eliminates command decoders just needs a router to route commands or data to components*
 - *Enables communication between components*
- Adopt messaging bus and data standards for use on-board to allow situational awareness, communication and collaboration between spacecraft components. Such changes could have dramatic effect on:
 - *Resiliency*
 - *Autonomy*
 - *New capabilities*
- Make appropriate spacecraft components reprogrammable to enhance capabilities
- Adopt standards for up/down link structure & data formats especially T&C
 - *Simplifies ground interface and possibly data routing on ground*

None of this stifles innovation of spacecraft bus or component design



Summary

- Possible future system features:
 - *Infrastructure that is in a constant state of evolution being quickly responsive to program needs and outside threats*
 - *Satellite contact by program need, not schedule, virtually anywhere on-orbit*
 - *Virtual control “stations” that are disaggregated - any operator position from anywhere there is appropriate connectivity*
 - *With appropriate cyber protections, use of the commercial cloud to enhance reliability and resiliency*
 - *Use of “machine learning” to decrease operator workload and error*
 - *Use of standardized presentation layer across systems to reduce training and isolate operators from infrastructure changes*
 - *Satellites where on-board systems can collaborate*
- These changes offer new, exciting capabilities at a possible lower cost for development and operations

The technology is here today, the future is limited by imagination and the desire to change

