

Reducing O&M Costs by Breaking Paradigms

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Problem Statement

- ▶ **O&M Costs make up a large portion of system costs**
Realizing serious O&M cost savings requires a shift in philosophy for a group of ultra-conservative people

- ▶ **We do it to ourselves, we find ways to add cost into the design which also translates to higher O&M in the name of flexibility and risk reduction**
 - **Both risk reduction & flexibility are desirable, but like everything else, must be taken in moderation**

Today's technology can significantly reduce O&M costs for space systems

List of Paradigms and Partial Truths Resulting in Added System Costs

- ▶ **“We never met a telemetry measurement we didn’t like”**
 - **If it can be measured, then collect it and send it down to the ground**
 - **Just because you bring it down doesn’t mean you have to look at it**
- ▶ **Geostationary spacecraft require 24 hour operations**
 - **What else would we do with the ground station and personnel when it wasn’t in communication with the spacecraft?**
- ▶ **Leo spacecraft MUST be contacted a minimum of once per revolution or they become lost in space or worse**
- ▶ **Maximizing COTS software results in the cheapest possible command & control system, and the easiest to maintain**
 - **How much could a little bit of glue code/”middleware” cost?**
 - **What do you mean you no longer support that version of your product?**

- ▶ **An adequate ground system requires a minimum of 10% of the overall program budget**
 - **You want me to command and control my extremely expensive space vehicle on a PC architecture!?**
- ▶ **Never, ever let the spacecraft enter into autonomous mode regardless of how great the autonomous mode design**
- ▶ **Always let the spacecraft enter autonomous mode regardless of how competent the operators are**
- ▶ **Spacecraft require live operations personnel to be present as much as possible (usually 24 hours a day) to monitor and prevent the following activities :**
 - **Initiation of spacecraft autonomous modes and/or redundancy switching**
 - **The ground based expert system detecting a problem and initiating action without operator intervention**
 - **We're looking for someone to blame this on**

- ▶ **Lights out ground terminal**
 - Automatic real-time diagnostics and fail-over to redundant units
 - Reliable communications links to/from remote ground terminals

- ▶ **Unmanned/Partially manned command and control centers**
 - Rule based expert system in the front room to replace cheap operators
 - Spacecraft engineers in the back room can be on call or at the factory

- ▶ **Spacecraft and/or ground system calling for help**
 - Put a cell phone antenna on the spacecraft have it call for help
 - Ground expert system pages spacecraft/ground anomaly team

- ▶ **Autonomous spacecraft operations**
 - Multi-level safe modes
 - Autonomous switching to redundant equipment
 - House keeping (e.g. momentum unloading)
 - Upload of ephemeral data from ground for auto sun tracking

- ▶ **On board telemetry monitoring & reduction**
 - Record all telemetry on board for TBD time period
 - Dump selected telemetry (yellow/red OOL) to ground and discard the rest
 - Only send down telemetry on change

- ▶ **Autonomous ground operations**
 - Autonomous switching to redundant equipment
 - Ground expert system pages spacecraft/ground anomaly team

- ▶ **PC based C&T systems**
 - Pentium/Pentium II with telemetry and command processing cards
 - Adequate processing speed, storage and memory exists as of yesterday
 - Fraction of the cost of COTS C&T software
 - Require no long term maintenance contracts at 25 - 35% annually, if it breaks throw it away, and use the spare

 - Anomaly response team can respond 24 hours a day from anywhere a pager and modem equipped lap top PC can go

- ▶ **Cost Trade Analysis**
 - Is the level of additional outage worth the savings?
 - How much is that additional .1 to 5 percent availability worth?
- ▶ **Spacecraft designed to take care of themselves probably will if we let them**
 - If we can't bring ourselves to do so, then why not offset the additional O&M cost with a reduction in the amount of on-board autonomy, especially in the case of GEO or other highly eccentric orbits
- ▶ **Move away from building systems that provide “Just in Case” solutions towards systems that provide “Just in Time” solutions**
- ▶ **Can we adopt any part of the Iridium commercial solution to fit DoD/NASA needs?**
 - **First to Market - *no time for complexity***
 - **Bare bone basics for O&M - *high S/C to operator ratio***
 - **At this per vehicle cost we can afford to lose a few - *On orbit spares***