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How TacSat-2 is Proving the Military Utility of Web Enabled Space Operations

Terrance Yee
MicroSat Systems, Inc.

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HOW TACSAT-2 IS PROVING THE MILITARY UTILITY OF WEB ENABLED SPACE OPERATIONS

By Terrance Yee, Systems Engineering Manager, MicroSat Systems, Inc., Littleton, CO

ABSTRACT

MicroSat Systems, Inc. (MSI) recently participated in the launch and early orbit operations of TacSat-2. MSI provided the bus for this spacecraft and worked with a number of other organizations under the auspices of the Air Force Research Laboratory at Kirtland AFB to support integration, test, launch and operations activities. One of the most innovative aspects of this mission is the use of the Internet and World Wide Web to support operations. The utility of these methods was extensively demonstrated during the recovery of the mission following the early loss of communications due to ARTS ground system configuration mistakes.

In this paper we will describe the capabilities of the TacSat-2 ground system to allow collaboration of a geographically diverse team. We will discuss the implications of these new capabilities on operational TacSat type vehicles and the systems they support with an emphasis on the utility provided to the military end customer. The calculation of such utility is peculiar to the Responsive Space paradigm because great emphasis is placed on the timeliness of delivery of critical information to lower echelon commanders rather than the sheer quantity and quality of total information produced which is more germane to strategic assets. The Internet accessible tools created for the TacSat-2 ground system dramatically alter the utility calculations for these types of missions.

We will also examine in detail several use cases from the first month of operations that exemplify the new capabilities and highlight their utility. These include cases of time critical responses to demand for new tasks as a result of the nature of the mission recovery where members of the technical team not in the mission operations center generated commands across the internet for operators to authenticate and execute, cases where collaborative planning of daily activities was supported by online tools, cases where international cooperation supported technical analysis of state of health and cases where real time pass support was coordinated across four states and two simultaneous communications links. We will also discuss how the use of the Internet has standardized several telemetry products and allowed the creation of third party tools to support telemetry trending and real time notification of spacecraft events.

INTRODUCTION

TacSat-2, shown in Figure 1, is the first experimental TacSat to be launched and among its innovations is the extensive use of web-based tools for operations. The character of some of these tools may not be unique in satellite operations but they have never been applied in such a central role in a USAF mission before. Thus TacSat-2 provides an opportunity to evaluate the utility of these tools in a military setting and examine their particular strengths and weaknesses, especially as they relate to such a security-conscious endeavor and the special application of responsive space where accessibility and timeliness are critical metrics.

Figure 1 – TacSat-2 Pre-Launch

TACSAT-2 CAPABILITIES

TacSat-2's web/internet based capability has four principle aspects. First, the primary telemetry display system (the Remote Intelligent Monitoring System or RIMS) was designed by Interface Control Systems (ICS) to be web accessible from the beginning of their development. A central server decommutates the incoming telemetry and serves it out to any number of clients which can be connected either on the local area network within the Mission Operations Center (MOC) or via secure website. This system was successfully developed during the I&T phase where it was used and tested extensively. The system went "live" over the web interface about a month prior to launch, in time for the final operations rehearsals. All telemetry screens available in the MOC are viewable via the web interface from anywhere in the world. A sample of a typical RIMS screen is shown in Figure 2 below.

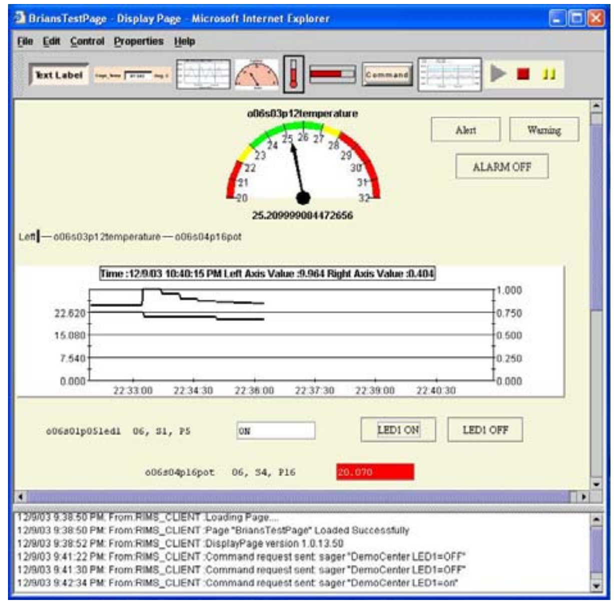

Figure 2 - Sample RIMS Telemetry Page

In a similar capacity, the ICS command generation tools and pass planner are also available on a separate branch of the TacSat-2 operations web page. These allow the user to generate pass plans for future contacts and populate them with the exact commands they want, including pull down menus to select any valid parameters. Previous pass plans are also viewable to allow a remote user to see what has been sent to the vehicle previously. Once the pass plan has been reviewed and approved in the MOC, the command sequences are compiled and the binary command strings are generated prior to the pass. Execution of these pass plans is accomplished through the mission controller's command screen. Commanding can also be accomplished via remote connection with appropriate security measures in place. To minimize security exposure, routine operations for TacSat-2 do not rely on web-based command execution.

The third web-based feature of the mission is the ability to access and trend historical telemetry data using a variety of tools. RIMS includes a trending tool that poles from one version of the telemetry database. It allows for searches that return up to 50,000 data points at a time across a range of telemetry specified by the user and exporting either excel or tab delimited ASCII data. A parallel government data center is also maintained and has a similar tool for trending. MSI developed its own tool, which requires the user to specify the APID that contains the telemetry mnemonics of interest. By narrowing the search to a specific APID or telemetry structure, this tool is much faster at generating output, so it works well for subsystem experts or particular payload scientists who are only interested in data of one type. Advanced Solutions, Inc., (ASI) MSI's subcontractor on TacSat-2 who provided the attitude control software and engineering, developed their own trending tool as well. ASI's tool is designed to mine a specific time range of database files for all the attitude control telemetry that is most frequently used and then automatically build dozens of graphs in MATLAB which are used to analyze subsystem performance.

Finally, MSI also created an e-mail/text paging service that constantly monitors the command history telemetry to look for either indications of trouble or events of specific interest to the user. When a certain key word or text string is detected, an alert is sent via e-mail and text message to the user's phone. This allows engineers and scientists to respond to emergencies as quickly as if they were in the MOC 24/7.

UTILITY METRICS FOR RESPONSIVE SPACE

Military utility can be a difficult term to define. For the purposes of this exploration, we shall define the military utility as the product of 1) how important the intended function is to the outcome of the conflict/operation and 2) how effectively the method performs the intended function.

Exploring further, the first aspect can be vary greatly depending upon the specific campaign or application. For Operationally Responsive Space (ORS) applications, one of the key functions is to place the spacecraft's command and telemetry capabilities in the hands of the combatant commanders directly. Another key function is to respond to call up within a week. Finally, ORS must be a joint operation across all service branches. These three functions, among the many possible functions within responsive space, appear to be the primary areas where web and Internet accessibility can show inherent utility.

To determine how effective these features are, we need to quantify the effectivity in terms such as timeliness, relative cost effectiveness, and minimum deployment effort.

UTILITY EXAMPLES FROM OPERATIONS

During the days following the launch of TacSat-2, the ground system was methodically disassembled in the effort to isolate the source of the commanding error discussed in AFRL press releases. When the ground station configuration issue was resolved, the spacecraft was found to have followed the dictates of its fault protection design and retreated to a minimum power state with no active attitude or thermal control. The resulting tumble had kept the vehicle in a safe thermal state but the battery was at a low level, barely sufficient for an attempt to regain control over the vehicle attitude. Without our web-enabled telemetry and command systems we were reduced to a basic command line interface (shown below in Figure 3) and a single monitor that all key personnel had to huddle around to view telemetry. As such we could not effectively assess progress in our recovery efforts or even trend data, except by manual tracing of screen displays created from live pass info only. In addition, all support personnel who lacked clearance to enter the MOC directly were completely cut off.

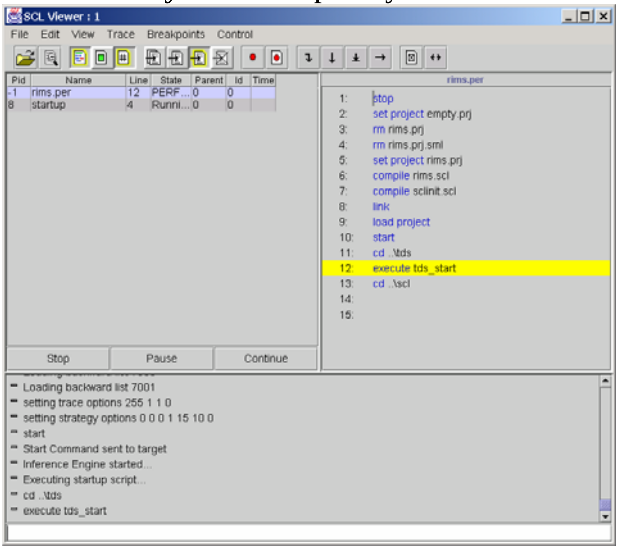

Figure 3 – Basic Command Interface

The operations team worked non-stop for a day to re-establish our full web capability so the entire set of operations tools and support personnel could be brought to bear on the problem. In the meantime, we devised a step-by-step process to regain full control of the vehicle using minimal power. Operationally, we mostly monitored the situation as best we could and waited for our full command and telemetry capability to be restored before attempting our risky recovery, since the vehicle seemed essentially stable.

Within three passes of restoring telemetry capability via the web, the engineers at Broad Reach Engineering were able to determine that the vehicle battery status had changed and was now definitely trending downward. Our spacecraft tumble had rotated the arrays further from the sun and thus it was time to enact our recovery plan. Mission controllers scheduled every available AFSCN contact for the next 12 hours, which meant 16 contacts. The "High Tempo Operations" allowed the team to treat the shift as one extremely long, complicated pass in several parts. During this period, the mission planner compressed the work of four full days into this time as well as kept an arsenal of nearly two dozen contingency procedures on deck and ready to activate at the touch of a button.

Teams of engineers in Colorado, Arizona and outside the MOC at AFRL in New Mexico kept constant watch over the telemetry and supported to MOC personnel by conducting detailed trending analysis and performance predictions for power, attitude control state, and thermal state. This allowed the team to accurately assess progress throughout the night and most efficiently and quickly move the recovery from one step to the next. Finally, at about 6 AM on December 20, TacSat-2 achieved safe mode with the arrays pointed at the sun with the ACS system fully operational and the thermal control system functioning. Later analysis by Millennium Engineering Inc. would show that had the recovery efforts started as little as one orbit later or taken one orbit longer, the spacecraft battery would have run out, leaving the vehicle in a potentially unrecoverable state. In this first flight use of the web based telemetry system, the TacSat-2 team showed that this capability not only alerted the team to a critical situation, but also helped it recover in time to avoid potential disaster.

The second example of the power of web-based operations is less dramatic, but just as meaningful. Following the recovery of the spacecraft, the team made solid progress in commissioning the payloads and performing experiments per the operations plan. Thus, starting on Christmas Eve, the vast majority of the technical support team dispersed across the country for the holiday week. During the time between Christmas and New Years Day, the MOC was most frequently manned by just a single operator, with local and nationwide engineers supporting the pass operations by phone and internet. We were even able to resolve the occasional trip from nominal operations into safe mode with this remote support. In the New Year MSI developed its paging system, which allowed a further reduction in the manpower needed for normal operations. This allowed off-site engineers to reduce their support to little more than on-demand troubleshooting. On several instances since then, unexpected conditions would cause a pager alert to be issued and engineers away from the MOC logged into the system remotely and diagnosed the root cause and had a corrective action suggestion ready for the post pass meeting with less than 10 minutes turn around time.

In a similar manner, star tracker experts at Terma in Denmark were given access to just the telemetry related to their equipment flying on TacSat-2, shown in Figure 4 below. Thus, they were able to confirm in the first week of the mission that the tracker was working exactly as intended and that the new baffle performance exactly matched predictions while taking up none of the operator's precious time and attention. Later, they were able to work with MSI to produce command sequences to allow the tracker performance to be further optimized. Thus, the ability to finely and automatically control data access provides the opportunity to receive support from non-US suppliers on even sensitive missions.

Figure 4 – Terma Star Tracker

Similarly, payload experts from both coasts and several states in between have participated in the checkout and optimization of their experiments without setting foot in the MOC, including building commands for the MOC to execute. Even more importantly, the mission operations team has demonstrated that command execution can also be passed to remote operators. In one case across the internet, several times from a Common Data Link terminal at China Lake (the same kind used for UAV command and control), and in one case, accessibility was verified from the WAN of a local coffee shop, although no commands were actually sent in that last test. Exercises in the coming months will demonstrate the utility of putting this direct control and receipt of data in the hands of warfighters in the exercise theater.

EVALUATION OF TACSAT-2 CAPABILITIES

As discussed above, the three primary areas of the ORS mission that are improved by web and Internet operations are accessibility by combatant commanders, rapid call up of capability, and ability to facilitate joint operations. The three metrics to be rated are timeliness, cost effectiveness, and ease of implementation.

Let us examine the TacSat-2 capabilities demonstrated with regard to the first mission area. The TacSat-2 capability to allow commanding and telemetry access to anyone with an Internet connection and the proper password translates very well to this ORS application. In this case, the use of secure connections via SIPRNET seems to be the key prerequisite for access. SIPRNET access appears to be available for a wide set of missions and campaign environments. This capability offers huge improvements in timeliness compared to the current paradigm of nationally controlled assets with centrally processed and disseminated data. Cost effectiveness is also a clear improvement in this area for the ORS application. While there is some initial investment in the server and software, the system maintenance and use are extremely low cost methods of pushing this capability to the field commanders.

Finally, ease of implementation is also ranked very high. As an analog, the Danish participants were able to fully participate after just three e-mail exchanges to 1) set up passwords and accounts 2) provide basic navigation instructions and 3) provide initial setup instructions which were limited to installing the latest JAVA update and configuring browser security features. Total instructor time was about ½ hour, while initial self-guided exploration of features takes about an hour or two.

Considering the second ORS objective, the web and Internet capabilities contribute to rapid call up by allowing the operations support team to remain on standby performing other tasks while awaiting the call. Once call-up has been issued, the web capability limits the amount of travel necessary to support a launch and early checkout campaign and at the same time, the use of a browser based interface means there is essentially very little “retraining” period to get used to the system again. While these effects have only a moderate impact on the overall timeline compared to the preparation of the space and launch vehicle, the web tools are still rated highly for timeliness, cost effectiveness, and ease of implementation in this scenario.

Finally, the web-based operations have been shown to be effective at allowing collaboration between a dozen groups across the US including JPL, AFRL, NRL and even extending to international support for some hardware. Extending this success to a joint military operation poses no significant technical or bureaucratic challenges, however, the proof of the effectiveness of the process being developed will come during the exercises in the months ahead. Regardless of the level of success of these processes, these capabilities still come at a very low dollar cost. If current processes are accurate predictors, the timeliness of this solution will still be several orders of magnitude of improvement beyond the current state of the art and there are no significant technical barriers to implementation.

CONCLUSIONS

The web-based operational capability being demonstrated by TacSat-2 offers significant improvements over traditional operational military systems. These capabilities have already proven themselves to be extremely valuable in the early on orbit operations, greatly contributing to the team’s ability to successfully recover from initial challenges and demonstrating significant efficiency advantages. The ease of use of this system, the low implementation cost, and the real-time nature of the interactions all contribute to the high military utility of these capabilities in relation to the ORS mission. Having operated TacSat-2 with these advantages, it is difficult to envision a fulfillment of the ORS promise without the use of these or similar web capabilities.

ACKNOWLEDGEMENTS

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