Transitioning Research to Operations: Transforming the "Valley of Death" Into a "Valley of Opportunity"

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Introduction

Transitioning technology from research to operations (R2O) is difficult. The problem's importance is exemplified by its appearance at the top of the "Key Issues 2013" list of the American Institute of Aeronautics and Astronautics (https://www.aiaa.org/KeyIssues2013/). Although the R2O gap is often called the "valley of death," a recent *Space Weather* editorial called it a "Valley of Opportunity" [*Robinson*, 2012]. As *Siscoe* [2006] noted, there are significant opportunities for space weather organizations to learn from the terrestrial experience. Dedicated R2O organizations like the test beds described by *Ralph et al*. [2013] are a common approach to improving terrestrial weather forecasting. Here we present experience-proven principles for establishment and operation of similar space weather organizations, public or private.

These principles were developed and demonstrated by NASA at the Applied Meteorology Unit (AMU) and the Short-term Prediction Research and Transition (SPoRT) Center. The AMU was established in 1991 jointly by NASA, the U.S. Air Force (USAF), and the National Weather Service (NWS) to provide tools and techniques for improving weather support to the Space Shuttle Program [*Madura et al*., 2011]. The primary customers were the USAF 45th Weather Squadron (45 WS) and the NWS Spaceflight Meteorology Group (who provided the weather observing and forecast support for Shuttle operations). SPoRT was established in 2002 to transition NASA satellite and remote-sensing technology to the NWS [*Jedlovec*, 2010]. The continuing success of these organizations suggests that the common principles guiding them may be valuable for similar endeavors in the space weather arena.

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Independent Budget and Management

When budgets or personnel ceilings are reduced or workload increases, R2O departments within operational organizations often suffer since operations take priority. Independent funding and management of R2O protects it from being cannibalized to cover operational shortfalls and optimizes the focus of R2O activities.

The AMU demonstrates this principle. Funded and managed by NASA, it does not depend on its operational customers (USAF and NWS weather support organizations) for funding or staffing. Customers provide important resources like work space, but independent funding removes temptations to use the AMU as an "All-purpose Manpower Unit." The AMU continues to function after two decades despite several severe budget reductions in operational programs. Likewise, SPoRT is supported through NASA core funding to demonstrate the utility of NASA data such as shown in Figure 1 to the NWS. This autonomy from operational constraints also allowed SPoRT to grow recently with additional funding from NOAA's Proving Ground activities [*Goodman et al*., 2012].

Presently, most space weather R2O functions are performed within a larger research or operational organization, with some individuals performing both functions. See, for example, http://ccmc.gsfc.nasa.gov/about.php. In contrast to the AMU and SPoRT examples, in one case, the R2O responsibility was appended to an explicit space weather research mission. Further, a space weather R2O organization with multiple sponsors would not only be able to pool resources and have broad reach back for expertise; it would be inherently protected from budget cuts as many agencies prioritize external obligations.

Structure and Staffing

The structure and staffing of R2O organizations must provide sufficient technical competence to evaluate and tailor new technologies and techniques to the user's requirements. This typically necessitates staff with both advanced technical degrees and awareness of operational

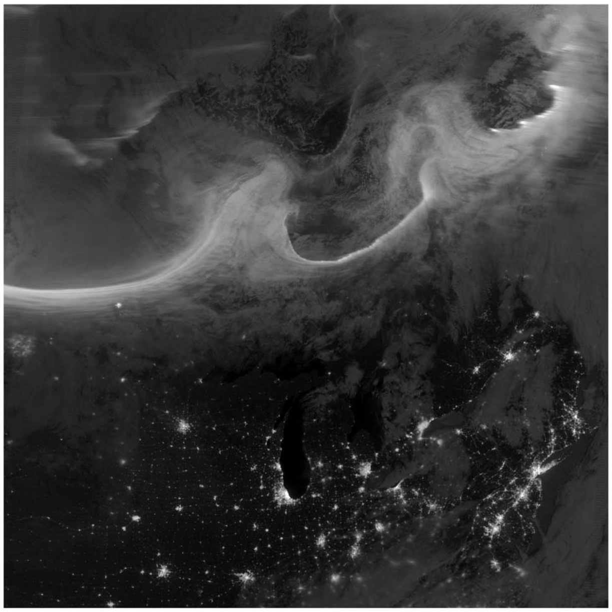

Figure 1. Nighttime image over northeast U.S. and southeast Canada from October 2012 for the day-night band on the Suomi National Polar-orbiting Partnership satellite. The day-night band detects reflected moonlight from clouds (gray areas), fog, smoke, light emitted from cities (bright white regions), fires, the aurora borealis (swirling white areas in the upper portion of the image), and other sources. Photo credit: NASA's Earth Observatory.

constraints and limitations. The structure must allow a flexible strategy in assigning staff to projects so that each has the requisite complement of technical skills and operational experience.

The AMU staff includes advance-degreed atmospheric scientists from a contractor and from NASA. Staff members typically have experience in both operations and research. Each project has a primary investigator who works with a liaison from the operational customer throughout the project. The appropriate staff expertise and pairing with an operational liaison is a critical component to the success of the organization. Alternatively, SPoRT is organized into functional groups within the R2O process: (1) modeling and data assimilation, (2) product analysis, (3) transition, training, and assessment, and (4) decision support systems. Each structure (AMU and SPoRT) has strengths and weaknesses, but the use of a consistent, coherent approach tailored to the way the respective organizations interact directly with their customers works well in both cases.

In the space weather domain, when opportunities arise, the strategic approach exemplified by AMU and SPoRT may yield considerable benefits: specifically, explicitly incorporating operations and research backgrounds into future staffing objectives.

Scope Limited to R2O

Limiting the scope of technology transition organizations accomplishes several purposes. Excluding pure research deters R2O scientists from being distracted by the charm of basic science and keeps them focused on delivering functioning operational tools quickly. Limited scope also eliminates the organization being perceived as a research organization of little practical use to operations. Excluding operational functions reduces the risk of being subjected to inflexible and expensive operational configuration management or certification. The R2O organization bridges the R2O gap as shown in Figure 2 for the AMU.

Early in its existence, the AMU was faced with eviction from its facility colocated with the 45 WS on the grounds that "a research facility does not belong in an operational building." On the other hand, great effort was exerted to avoid having the AMU equipment and software configurations frozen under rigid configuration management because they were seen as "operational systems." Because the NASA/USAF/NWS agreement establishing the AMU expressly barred the AMU from both basic research and direct operations, both efforts were defeated.

Explicit delineation of an R2O organization as neither research nor operations is rare in the space weather R2O enterprise. For space weather organizations, facing the challenges identified in the two paragraphs above, making this delineation explicit could be both a valuable guiding principle and a powerful defense mechanism.

Tasked by Customers

The user should be the focal point for all R2O activities. With task descriptions and assignments coming directly from users, effective technology transfer can be achieved to meet immediate and specific needs. Working closely with customers, R2O researchers provide the evaluation necessary for an effective cost/benefit analysis. Failure to critically evaluate a proposed technology upgrade in an operational setting can result in wasted resources or missed opportunities. Involving the end user in the entire process increases "buy-in" for the product.

The AMU holds quasi-annual tasking meetings to determine work for the following year. Weather support organizations who receive AMU products and operational recipients of weather support services are invited to submit proposed tasks prior to the meeting and to attend and participate in their refinement and prioritization.

SPoRT routinely has discussions with users about forecast challenges and problems. Potential solutions are considered; plans for refinement, transition, and assessment of the solution developed; and forecaster training implemented. This paradigm has been extremely effective for the AMU and SPoRT.

In the case of space weather R2O, the burden for being user focused must be recognized as a joint one: the space weather user community is often vague about its specific needs, for reasons of security, commercial competitiveness, or lack of awareness; and the R2O community is often too

Figure 2. Drawing showing the function of the Applied Meteorology Unit as a bridge between research and operations rather than a primary practitioner of either.

heavily influenced by the priorities of the research community. It must be recognized that the operational space weather forecaster is not necessarily the end user of R2O activity—that end user is often a satellite operator or an anomaly analyst. Successful R2O after the AMU/SPoRT model requires outreach to and routine engagement with specific space weather end users.

Teaming With Customers

Colocation

The *National Research Council* [1988] recommended an "Applied Research and Forecasting Facility" be established to promote the development and application of new measurement technology and new terrestrial weather analysis and forecasting techniques to improve support for space operations. The recommendation suggested collocating the facility with the operational customer to allow the facility's scientists to interact with its customers on a daily basis to learn and understand the customer's mission. This also familiarizes customers with the transition facility's capabilities and limitations thus enabling effective use of the resource.

The AMU is located adjacent to Range Weather Operations at Cape Canaveral Air Force Station. The forecasters, launch weather officers, and AMU staff are in daily contact. SPoRT is colocated with the Earth Science Office of Marshall Space Flight Center, academic and research capabilities of the University of Alabama Huntsville, and the Huntsville NWS Weather Forecast Office (WFO). This unique collocation arrangement of research and operational weather agencies with academia enhances collaboration and two way interaction for the end-to-end R2O capability developed by SPoRT. SPoRT liaison staff uses the close relationship with the Huntsville WFO as a gateway for active R2O activities with over 20 other WFOs and several National Centers across the country.

Of all the lessons learned from AMU and SPoRT, collocation is probably the most difficult for the space weather enterprise, as it can be difficult to persuade highly skilled R2O professionals to relocate. In selecting locations for new R2O organizations, collocation can be incorporated from the beginning; for established organizations, opportunities to collocate should be evaluated when they arise.

Continuous Interaction

A common roadblock to successful R2O is the lack of alignment of projects to customer expectations. Continuous customer interaction during task execution assures that there is no drift in the focus of the project as the R2O activities progress. Continuous involvement ensures that customer insight is captured and incorporated thus producing a product that is useful in the operations environment.

Such continuous customer interaction recently benefited an AMU project to develop a tool for the 45 WS that displays vertical wind profiles from local weather balloon data and model predictions [*Baumann and Flinn*, 2013].

In the space weather context, this lesson is probably most useful as an incentive to end users to remain engaged in product development after they have articulated their needs and requirements. The space weather R2O staff should incorporate this lesson into planning for intermediate design and implementation reviews for products under development and ensure that end users are represented at such reviews and have some level of sign-off authority.

Flexibility During Task Execution

Flexibility during task execution is important to effective R2O. As projects progress, initial approaches may fail or yield to better alternatives. Flexibility allows projects to be canceled, modified, or replaced. Decision points can be incorporated into project schedules to build in flexibility. Flexibility should be encouraged even when not formally scheduled.

An AMU project undertook to develop applications for the analysis software on a new weather radar acquired by the 45 WS [*Short et al.*, 2000]. Unfortunately, the required programming environment turned out to be unavailable because it was proprietary. However, the project team saw an opportunity to improve the radar scan strategy for 45 WS operations. The customer was advised and concurred with redirecting the task. The new scan strategy increased the radar's vertical resolution 37% in the atmospheric electrification layer over the Cape Canaveral launch pads, significantly improving operational lightning support.

For space weather, this lesson suggests that contracting mechanisms for R2O activities should have clearly defined and minimally cumbersome mechanisms for updating requirements, tasking, etc. Because satellite anomalies can arise suddenly and often require specialized products that become irrelevant when the affected satellite is retired, the R2O organization must be agile enough to respond while a response is relevant.

Conclusion

In conclusion, the principles for successful R2O learned from the success of the AMU and SPoRT can be applied in the space weather domain. They can inform how R2O organizations are sponsored, funded, staffed, and structured, as well as how their scope is defined, how they are tasked, how they interact with their customers, and how they respond to change. Although this article is primarily directed at the government sector, application of many of these proven principles should similarly enhance the effectiveness of commercial sector R2O. The AMU and SPoRT models suggest that space weather R2O organizations would benefit from having (1) joint sponsorship by customer and research agencies, (2) an independent budget, (3) structural and functional independence from research and operations, and (4) colocation with operational customers and research support base where possible.

These dedicated R2O staffs would combine research and operations experience either individually or collectively. The R2O organizations would aggressively seek out frequent, direct interaction with their end users to turn the user's requirements into taskings and to obtain feedback on R2O product development and implementation. Finally, the R2O organizations must remain flexible so that they can address challenges within the R2O activity and new challenges from end users in a timely manner.

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