Space Policy 29 (2013) 76–82

Contents lists available at SciVerse ScienceDirect

Space Policy

journal homepage: www.elsevier.com/locate/spacepol

Policy for robust space-based earth science, technology and applications

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ARTICLE INFO

Article history:
Received 17 April 2012
Received in revised form
18 July 2012
Accepted 23 July 2012
Available online 29 January 2013

ABSTRACT

Satellite remote sensing technology has contributed to the transformation of multiple earth science domains, putting space observations at the forefront of innovation in earth science. With new satellite missions being launched every year, new types of earth science data are being incorporated into science models and decision-making systems in a broad array of organizations. Policy guidance can influence the degree to which user needs influence mission design and when, and ensure that satellite missions serve both the scientific and user communities without becoming unfocused and overly expensive. By considering the needs of the user community early on in the mission-design process, agencies can ensure that satellites meet the needs of multiple constituencies. This paper describes the mission development process in NASA and ESA and compares and contrasts the successes and challenges faced by these agencies as they try to balance science and applications within their missions.

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1. Introduction

Satellite remote sensing technology has, over the past six decades, contributed to the transformation of multiple earth science domains. Space-based earth observations have contributed to quantitative understanding of processes and interactions between the land, ocean and atmosphere, as well as enabled real-time monitoring of weather, agriculture, water supplies, snow pack and a myriad of other environmental parameters, enabling a better understanding of important societal benefits. As the number and capability of space-based sensors has expanded, the amount of data available for use in environmental management, decision making and operational modeling environments have also increased. Using satellite remote sensing for practical decision making and action, now involves a broad community individuals, institutions, and organizations both public and private [1]. This broad constituency has led to the perception that earth science missions should be more closely aligned with the needs of the user community [2].

Because user requirements can be poorly aligned with mission characteristics required to obtain scientific observations, technological advances or strategic integration of missions wanted by space agencies, there is a need for a more comprehensive policy on the way the broader user communities influence new science missions. Policy guidance can influence the degree to which user needs influence mission design and when, and ensure that satellite missions serve both the scientific and user communities without becoming unfocused and overly expensive. By understanding and considering the needs of the environmental data and applied research user community early on in the mission-design process, agencies can ensure that satellites meet the needs of multiple constituencies.

This paper examines the experience that the US National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) have had in their efforts to increase the integration of user communities into mission development. ESA has begun the Global Monitoring for Environment and Security (GMES)

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0265-9646/$ – see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.spacepol.2012.11.007

program, whose focus is to convert observations into environmental services. With the publication of the 2007 US National Research Council's Earth Science Decadal Survey, NASA has begun working to change its mission development process to incorporate the needs of satellite data users into mission development [3]. The paper describes the mission development process in both space agencies and compares and contrasts the successes and challenges faced by these agencies as they try to balance science and applications within their missions.

1.1. Background

As the scope of data products derived from satellite-derived information has expanded over the past six decades, the incorporation of Earth science products into the mainstream environmental, meteorological and other user communities has increased [4]. This includes the movement of essentially science-produced research products derived from missions into operational observations, such as those that the National Oceanographic and Atmospheric Administration (NOAA) are responsible for providing. Whitney and Leshner define research activities as those that "develop scientific understanding of important processes and/or demonstrate the capabilities of new analysis, modeling techniques, or measurement techniques, typically through acquiring, calibrating, and characterizing a specific set of measurements" [5]. One can consider a spectrum of activities that begin with mission design and end with operational production of measurements that are ingested into algorithms and models to produce data products. Applications of remote sensing are very diverse and include scientific analysis, periodic assessments of land cover, one-time decision making assessments, or operational use in models such as weather prediction [6–9]. Operational activities "routinely and reliably generate specific services and products that meet predefined accuracy, timeliness, and scope/format requirements, as well as disseminating or making them available to a variety of users in the public, private, and academic sectors" [5].

Diverse communities have made efforts to move from an ad hoc approach of integrating scientific data into operational processes to a more systematic and flexible process that is funded by adequate resources. The 'Valley of Death' between research and operations, discussed in a 2003 National Academy of Sciences report, can be bridged with improved supporting infrastructure that links research to operations to the user community of satellite data [3]. Gilruth et al. (2006) describe efforts to develop performance metrics based on results from the US Congress-mandated, NASA-funded Earth Observing Systems (EOS) Data and Information System (EOSDIS) project. This project has worked to provide data and products relevant to global change research to a broad user community. Their paper provides clear examples of the specific benefits and uses of satellite observations in models and in decision-support systems across different US government agencies and private institutions [4]. This effort has raised NASA's profile as a provider of scientific analysis and resulting data product that can be useful for policy and decision-making processes.

In Europe, the Global Monitoring for Environment and Security (GMES) programme focuses on the implementation of a common European space policy, and the need to build environmental monitoring and research capability that will serve all nations in the European Union [10,11]. Like Gilruth et al., Brachet discusses how the implementation of GMES is focused on delivering information and services needed by user, ongoing assessment of how needs are being met, and developing an infrastructure required to provide these services. Metrics and deliverables were at the center of the relationship between users and producers, similar to those seen in EOSDIS [11].

Thus the increase in the use of satellite data beyond the research community and the ever increasing 'pull' or need for earth observations from user communities should affect how missions are designed and implemented [12]. Precipitation, vegetation, sea ice, atmospheric variations, land use and land cover, forest dynamics and many other remote sensing derived environmental variables are regularly used in the public, private and educational sectors [13–16]. As the need for these data expands, the tension between research and operational sensor design and product delivery becomes more acute. This paper examines how national space policy can ensure continual improvement of earth observations, while sustaining measurements in key areas to ensure support of decision makers.

2. Earth science at NASA

As the US civil space agency, NASA has the responsibility of communicating and applying its mission products to all interested US agencies. Thus, by fostering relationships with interested entities, NASA can strengthen the development of Earth science applications. The US National Research Council's (NRC) 2007 earth science decadal survey provided a broad set of new instruments, observations and climate data records [16]. The report addressed the importance of applications and "recommended a suite of satellite missions and complementary activities that serve both scientific and applications objectives for the nation". It stated that identifying and supporting applications of scientific data to obtain societal benefits from NASA missions should play an equal role during the formation and implementation of new missions to that of science and presented a vision for developing new satellite data products that have specific user communities' needs and requirements at the center of mission development. Meeting this objective will require a continual evolution in the way NASA and the earth science community does business. It will need to re-evaluate how it prioritizes, makes decisions and communicates with the user community. NASA must engage with communities of satellite data users early in process of mission development, and sustain the engagement for the entire life of the mission.

The US National Space Policy of 2010 states that one of NASA's goals is to 'improve space-based Earth and solar observation capabilities needed to conduct science, forecast terrestrial and near-Earth space weather, monitor climate and global change, manage natural resources, and support disaster response and recovery.' NASA has assigned the responsibility for defining, planning, and overseeing its space and earth science programs to the Science Mission Directorate (SMD). SMD organizes its work into broad scientific pursuits: conducting scientific exploration of the Earth, Sun, Solar System and Universe, enabled by access to space. SMD develops instruments and spacecraft to support NASA's science goals and sponsors fundamental research and analysis to advance scientific knowledge [17].

NASA's Applied Science Program, located within SMD, works primarily through partnerships with organizations that have established connections to users and decision makers. The program supports applied science research and applications projects to promote innovation in the use of NASA earth science, transition of applied knowledge to public and private organizations, and integration of Earth science in organizations' decision making and services, helping to improve the quality of life and strengthen the economy. The Program leverages investments made in other areas and works within the broader scope of SMD to achieve its goals, competing with science, engineering, financial and strategic interests within and outside the organization.

2.1. Applications of earth science

Despite the existence of a NASA strategy for encouraging earth science applications, it has become clear that greater attention is