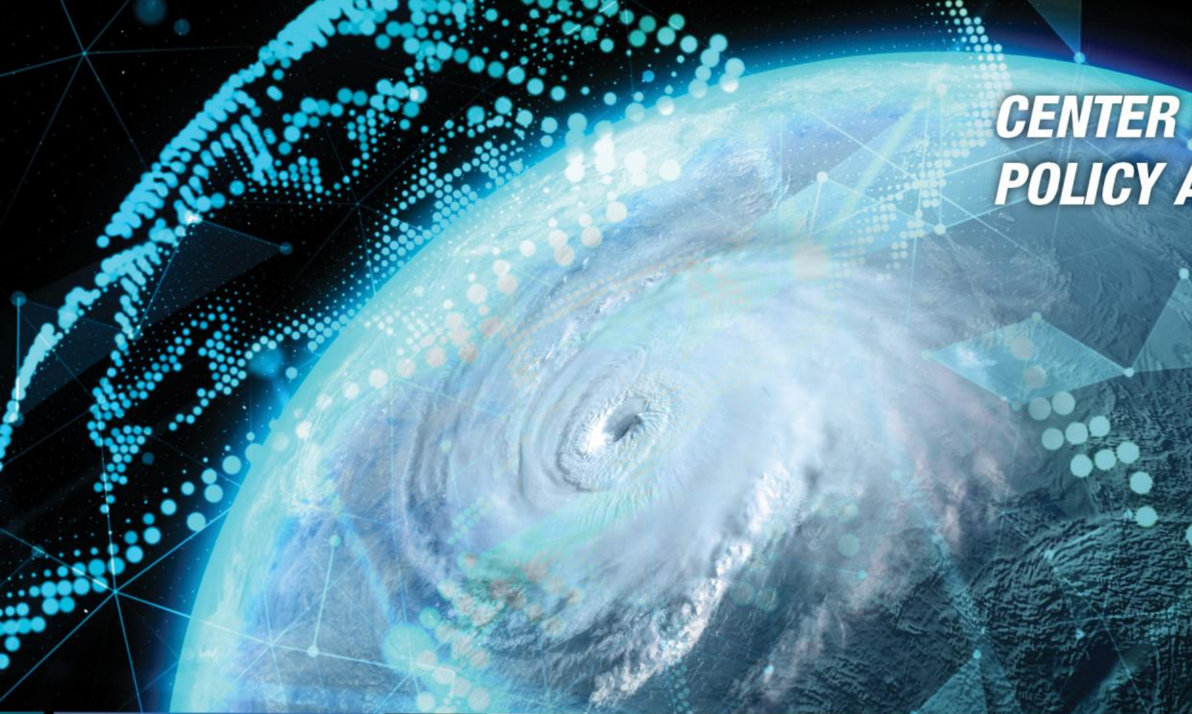

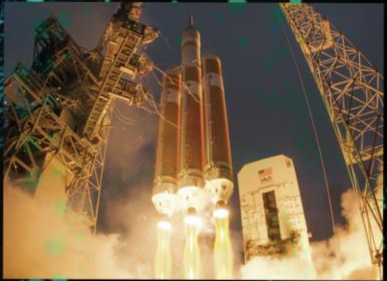

CENTER FOR SPACE POLICY AND STRATEGY

JUNE 2021

CLEARING SKIES IN THE FORECAST FOR THE NATION'S WEATHER SATELLITES

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Summary

U.S. space-based environmental monitoring (SBEM) systems acquired by Department of Defense (DOD) and Department of Commerce (DOC) provide critical weather and oceanic data to support military and civilian users. Over the course of decades, DOD has evolved to rely on a family of SBEM systems with critical civil elements to meet the full range of national security requirements. While the use of civil satellites is not unique to SBEM, the scope of DOD's reliance on a civil-military-international family of systems for SBEM has no analog across national security space. In fact, numerous agencies across the U.S. government rely on this combined family of systems SBEM architecture to satisfy user requirements. The National Oceanic and Atmospheric Administration (NOAA) and DOD sit at pivot points with a rare opportunity to plan the next generation of environmental satellites that will comprise the combined U.S. architecture out to 2040 and beyond. In parallel, China's muscular initiatives in the SBEM mission area threaten U.S. preeminence and introduce the risk of future reliance by global weather centers for operational forecast modeling on potentially high-quality data from an adversary. The alignment of future SBEM planning activities across the U.S. government combined with the emergence of the commercial sector presents a rare opportunity to conduct a national dialogue to explore a whole-of-nation approach to address strategic SBEM challenges. This paper proposes rationale for this dialogue, presents a conceptual approach to enterprise SBEM integration across the government, and connects enterprise integration to the advancement of national policy.

"Know the enemy, know yourself; your victory will never be endangered. Know the ground, know the weather; your victory will then be total."

—Sun Tzu

Introduction

With its combined civil and military space-based environmental monitoring (SBEM) capabilities, the United States has maintained global preeminence for nearly 60 years. SBEM capabilities can be simply thought of as weather satellites, though they do so much more. The operational space-based environmental monitoring systems of National Oceanic and Atmospheric Administration (NOAA) which resides in the Department of Commerce (DOC) and Department of Defense (DOD) represent critical infrastructure for national security and public safety and are essential to our nation's economic prosperity. But, if we do not develop a more coordinated U.S. governmentwide approach to developing SBEM capabilities, the United States could find itself at an international disadvantage. In particular, China is planning to fill potential capability gaps traditionally provided by U.S.

assets, putting both the U.S. and allies into the position of relying on an adversary for critical weather data.

NOAA's space-faring organization, the National Environmental Satellite, Data, and Information Service (NESDIS), satisfies U.S. domestic requirements for space-based environmental information through an exquisite suite of instruments in multiple orbital regimes combined with data from international partners. NOAA augments its data by ingesting observations from DOD's low Earth orbiting (LEO) Defense Meteorological Satellite Program (DMSP) satellites. In contrast to NOAA's ability to satisfy its priority user requirements through a civil architecture, DOD depends critically on a robust, joint military-civil-international SBEM infrastructure to meet warfighter needs. Both military and civil SBEM systems are susceptible to adversarial threats as with other non-SBEM space assets.[1, 2, 3] Civil SBEM systems, however, are not subject to equivalent resiliency and asset protection standards in the face of adversarial threats as are DOD systems. The scope of the U.S. reliance on civil systems in the SBEM mission-area to meet military and other national security requirements arguably has no equivalent in the space domain.

Increasing threats to space systems, persistent budget pressures, and the rise of new commercial space business models elevate the mutual benefits that could be realized from coordination and potential integration of efforts in SBEM across the government. Both NOAA and DOD are at strategic pivot points with a rare opportunity to collectively shape the future as they plan the next-generation systems that will operate to 2040 and beyond. This paper focuses on the opportunity in the context of the need to assess risk associated with relying on civil systems to meet military and other national security requirements. It proposes a conceptual framework to facilitate a whole-of-government approach to SBEM collaboration, leveraging existing White House-level entities and connecting the results of this enterprise-level collaboration with national space policy.

Civil-Military SBEM Ecosystem

A Collaborative Effort to Meet the Nation's Needs

SBEM systems have provided essential data to support military and other national security missions for over six decades. Needs span all military services with the United States Air Force (USAF) and United States Navy (USN) addressing requirements for the Army and Marine Corps, respectively. USAF historically shouldered the responsibility to acquire and operate SBEM systems to satisfy joint military needs. In this paper we reference DOD broadly, mindful that SBEM-related responsibilities and authorities will reside within multiple organizational elements across the department.

The core needs of military and civilian SBEM users are to characterize and forecast the state of the natural environment from the seafloor to the sun. While user priorities diverge across agencies, the superset of environmental data needs is shared. Table 1 contains a representative sample of environmental parameters collected from space for military and civilian use. Applications of these data include forecasting across all domains (atmosphere, oceans, terrain, space), extreme condition warnings for safety and infrastructure protection, situational awareness products, climate monitoring, and treaty compliance monitoring. While a detailed description of why these parameters are relevant to the warfighter is beyond the scope of this paper, we will describe three examples. Perturbations in the solar wind assist with prediction and characterization of geomagnetic storms that can threaten the health and safety of orbiting DOD assets. Total electron count is used to monitor ionospheric conditions that impact satellite navigation and communication. Soil moisture is a

Table 1: Common SBEM Needs
Cloud Imagery
Atmospheric Temperature Profiles
Atmospheric Moisture Profiles
Vertical Wind Profiles
Ocean Surface Vector Winds
Soil Moisture
Snow Depth
Sea Surface Temperature
Total Electron Count
Solar Wind
Energetic Charged Particles
Electric Field

Select list of environmental parameter requirements that are shared between civilian and military users.

critical parameter for trafficability forecasts that are critical for planning the movement of vehicles and troops on the ground.

Over time, DOD has increasingly relied on civil SBEM systems to provide core atmospheric and oceanic data. The importance of the SBEM mission to the joint warfighter is described in Joint Publication 3-14, *Space Operations*:

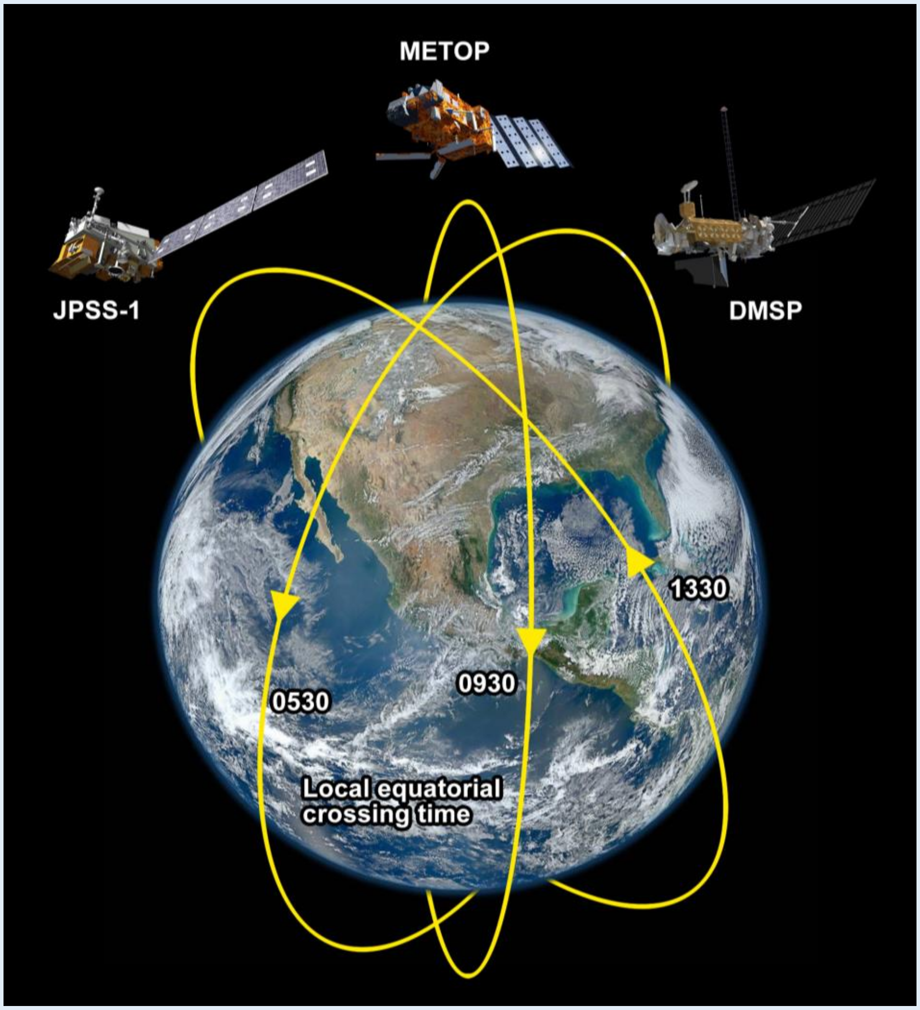
> Terrestrial environmental monitoring provides information on meteorological and oceanographic (METOC) factors in the maritime, land, and air domains that affect military operations. Space-based environmental sensing supports the development of METOC forecasts and assessments of environmental impacts on both friendly and threat military systems and operations. Environmental monitoring information includes data provided by non-DOD satellites, such as National Oceanic and Atmospheric Administration (NOAA) operational weather and NASA research satellites, as well as foreign satellites such as the European and Japanese geostationary weather satellites.[4]

A critical subset of civil and military SBEM requirements are satisfied through satellites that fly in sun-synchronous polar orbit described in more detail below. From the early 1960s until 1994, the U.S. operated separate military (i.e., DMSP) and civil (i.e., Polar Operational Environmental Satellite, POES) LEO environmental satellite programs. In 1994, the White House and Congress compelled DOD and NOAA to converge the polar programs (i.e., DMSP and POES) into the National Polar-orbiting Operational Environmental Satellite System (NPOESS). In February 2010, the U.S. cancelled NPOESS for overrunning its original cost estimates by several billion dollars and subsequently directed DOD and DOC to revert to developing separate military and civil SBEM systems. In order to establish expectations for continued civil-military coordination, the White House Office of Science and Technology Policy (OSTP) issued policy guidance for LEO orbital slot responsibilities between the agencies as follows: NOAA was responsible for the "early afternoon" and "mid-morning" orbits. DOD was responsible for the "early morning" orbit. The U.S. was to rely on NOAA's bilateral agreement with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) to satisfy the "mid-morning" requirement. The fundamental assumption was that each agency would maintain the continuity of both sounding (i.e., atmospheric profiles of temperature and humidity) and imaging capabilities to meet the common civil and military needs for environmental data from satellites in all three LEO polar orbits.[5] These responsibilities were codified in National Space Policy (June 2010):

> The Secretary of Commerce, through the NOAA Administrator, the Secretary of Defense, through the Secretary of the Air Force, and the NASA Administrator shall work together and with their international partners to ensure uninterrupted, operational polar-orbiting environmental satellite observations. The Secretary of Defense shall be responsible for the morning orbit, and the Secretary of Commerce shall be responsible for the afternoon orbit. The departments shall continue to partner in developing and fielding a shared ground system, with the coordinated programs operated by NOAA. Further, the departments shall ensure the continued full sharing of data from all systems.[6]

The updated Space Policy (December 2020) directed a continuation of the existing (June 2010) policy regarding LEO orbit responsibilities.[7]

The aforementioned 2010 and 2020 policy directives are the only existing national policy documents that explicitly address the relationship between DOD and NOAA with respect to SBEM operations and development. As documented in a U.S. Government Accountability Office (GAO) report to Congress in May 2010[8], decisions by both DOD and NOAA were anticipated to clarify whether the combined acquisition plans would meet both civilian and military user requirements. If DOD decided not to field either imaging or sounding capabilities in the early morning orbit, NOAA would need to consider investing in those capabilities independently. The reverse logic applied to DOD for any capabilities NOAA might choose not to pursue. A May 24, 2021 *SpaceNews* article, "A race against time to replace aging military weather satellites," provides a detailed accounting of DOD's pursuit of capabilities to replace DMSP.[9]



The U.S. works with EUMETSAT to fly satellites in three orbits that pass over Earth's polar regions and overfly points on Earth at the same local time each day. This is called a Sun-synchronous polar orbit. Denoted by the local time on the ground of the overpass, the weather community uses data collected in three such polar orbits commonly referred to as "early afternoon," "mid-morning," and "early morning." NOAA is responsible for the early afternoon orbit which crosses the equator at 1330 local time; DOD covers the early morning orbit (0530 local time equatorial crossing); and EUMETSAT fills the mid-morning orbit (0930 local time) via an agreement with NOAA. The expectation in national policy for the this three-orbit architecture is that each agency will maintain the continuity of both sounding (i.e., atmospheric profiles) and imaging capabilities. This three-orbit architecture provides satellite cloud imagery coverage over every point on the Earth at least every four hours. Vertical profiles of atmospheric temperature, moisture, and other parameters from this architecture comprise the core input to weather forecast models relied upon by both the military and civil communities for weather and oceanic forecasting. Slight variations in local crossing time are accommodated by the models in practice to allow for primary and backup satellites in each orbit. The illustration above reflects the current combined (U.S. and Europe) international SBEM architecture, including NOAA's JPSS-1 (primary) and Suomi-NPP (legacy/back-up) systems, EUMETSAT's Metop, and DOD's DMSP.

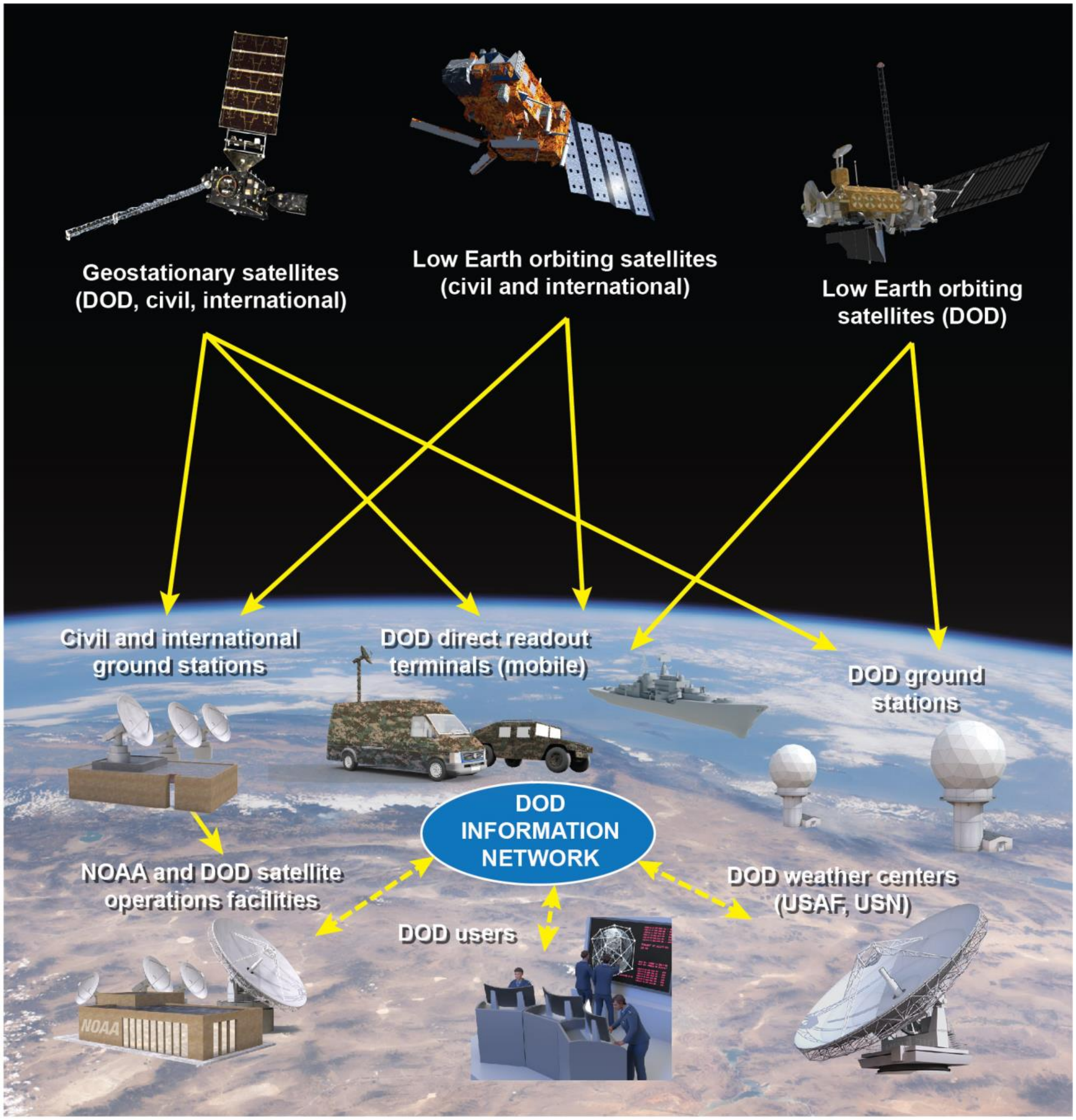
In the years following the collapse of the NPOESS program, NOAA acquired and fielded capabilities to replace its legacy POES satellites with the launches of Suomi National Polar-orbiting Partnership (S-NPP) in Fall 2011 and the first Joint Polar Satellite System (JPSS-1) in November 2017. Through its agreement with EUMETSAT, who has launched its series of Metop satellites into the mid-morning orbit, NOAA has met its LEO SBEM obligations under the 2010 policy. DOD satisfied its LEO SBEM obligations while meeting its priority warfighter requirements through the launch of DMSP-18 in 2009 and DMSP-19 in 2014. However, while the cloud imaging instruments continue to function, DMSP's atmospheric sounding capabilities have failed. China is poised to insert satellites into nearby orbits and share the data with U.S. allies and adversaries, filling a gap that could exist for the U.S. and its international partners when DMSP end-of-life is reached. See the expanded discussion in the inset box above for a more detailed description of the structure and rationale for the SBEM LEO architecture.

Building on the highly leveraged LEO paradigm, DOD's family of systems concept (Figure 1) incorporates instruments on platforms in GEO and extended orbits to satisfy the full set of warfighter and other national security requirements.[10] The family of systems includes two classes of U.S. military, civil, and partner (national and international) SBEM systems: LEO and GEO SBEM systems. DOD and NOAA are also pursuing an increasing array of commercial opportunities.[11] New commercial business models (especially for LEO platforms) may offer viable capabilities at lower cost points to augment or replace government owned/operated architectures.[12] For example, NOAA has awarded contracts to two commercial vendors in a data buy model to procure atmospheric profiles derived from a remote sensing technique called Global Navigation Satellite System Radio Occultation (GNSS RO).[13,14] Both NOAA and DOD are engaged with industry to explore the opportunities to exploit similar models for other SBEM sensor modalities.

In addition to LEO satellites (such as DMSP, JPSS, and EUMETSAT's Metop), DOD uses the NOAA Geostationary Operational Environmental Satellite (GOES) systems and similar international systems under international agreements through NOAA, such as the Europe's Meteosat Second Generation (MSG) and Japan's Himawari satellites. Figure 1 depicts a recent addition to the DOD family of systems called EWS-G, which is a repurposed NOAA GOES satellite that was repositioned over the Indian Ocean in April 2020 to support DOD's U.S. Central Command operations. EWS-G is a success story of DOD-NOAA SBEM collaboration.[15]

DOD leveraging of the civil and international community in space received greater emphasis with the issuance of the June 2020 Defense Space Strategy. This strategy provides guidance for achieving desired conditions in space over the next 10 years, including a phased approach for the defense enterprise to move with purpose and speed across three lines of effort:

- Build a comprehensive military advantage in space
- Shape the strategic environment
- Cooperate with allies, partners, industry, and other U.S. government departments and agencies[16]



←- - - -→ Data and products

←——→ Realtime SBEM data

Figure 1: Current operational view of the SBEM Family of Systems (military, civil, and international) DOD uses to meet its METOC needs.

The third element resonates with DOD's family of systems approach to SBEM. However, the extent to which it is pursued carries risk with respect to building a comprehensive *military* advantage in space since the allies and partners are primarily civil organizations whose operating objectives and mandates are generally not related to warfare. As noted throughout this paper, the extent of the reliance on civil SBEM systems (domestic and foreign) to meet critical warfighter requirements without a fallback plan, if these systems were to become unavailable during conflict, has no direct analog in any other mission area.

National Security Considerations

DOD reliance on domestic and international civil SBEM systems comes with operational risk to mission resiliency that must be mitigated or accepted. This is not to suggest that reliance on civil assets is not smart or preferred. Leveraging civil systems for military purposes under peace and wartime conditions may represent an optimal cost-benefit trade for DOD and the nation. However, civil SBEM systems are designed to maintain continuity in nonadversarial operating environments.

Although the U.S. has benefitted from a stable SBEM partnership with Europe since the 1980s, international partnerships generally carry more risk due to factors including local economic conditions and geopolitical dynamics. At any time, other nations may make decisions reflecting parochial interests that are not aligned with U.S. priorities. For instance, a civil or international partner could commercialize, delay, or cancel acquisition of space systems regardless of U.S. impacts. We note that partnerships between U.S. agencies are not immune to instability and misalignment of priorities—as exemplified by the implosion of the Landsat 7 partnership in the 1990s[17] and collapse of NPOESS in 2010.[18] An additional challenge is that DOD must rely, as a matter of policy, on NOAA to act as its surrogate in international civilian meteorological forums. NOAA serves as the U.S. lead, working through the State Department, to bodies such as the Coordination Group for Meteorological Satellites. The U.S. approach is different from other nations, such as China, who make no practical delineation between military and civil space assets. For the U.S., the current approach creates a situation where DOD's SBEM equities are not directly represented in international meteorological satellite forums.

Domestic and international civil systems are vulnerable to counterspace threats in certain military and geopolitical scenarios. At the same time, NOAA and allied international SBEM systems are not mandated to comply with the policies and protocols applied to National Security Systems, such as the Committee of National Security Systems Policy No. 12[19], that are more stringent than the standards applied to civil systems. This translates to the risk of disruptions to or degradation/denial of data in adversarial environments in which civil systems are not designed to operate.[20] We are *not* suggesting that the protection standards for civil SBEM be elevated to meet standards applied to DOD systems. We do suggest that the resilience of civil systems under adversarial operating conditions needs to be assessed by DOD within the context of their critical role in satisfying national security requirements.

Another security consideration is China's rise as a primary competitor to the U.S. in the space domain.[21] China has become active in the SBEM mission area—developing its own meteorological and oceanic observing satellites and actively seeking partnerships through civil international Earth observation forums. China launched its first Fengyun series weather satellite in 1988, becoming only the third country to do so, and has launched 16 Fengyun satellites to date.[22] The Fengyun series of satellites are administered by the Chinese Meteorological Administration with mission and overall capabilities roughly equivalent to DMSP. The Fengyun series appears to be a dual-use asset, built to meet the needs of the People's Liberation

Army Strategic Support Force and broader civil needs.

With the impending end-of-life of the DMSP satellites, international entities are aware of the gap in the early morning LEO sounding coverage and are considering non-U.S. alternatives. Bolstered by a request from the World Meteorological Organization, China is on track to launch imagery, sounding, and space weather instruments into the early morning orbit in 2021.[23] On March 15, 2017, the EUMETSAT Director-General and the China National Space Administration Vice Administrator "signed an agreement that provides the policy framework for the continuation and expansion of EUMETSAT's cooperation with China on monitoring the oceans, atmosphere, and climate from space."[24] The cooperation includes data exchange, scientific cooperation, and coordination of respective observing systems. The policy framework established by the EUMETSAT agreement with China "will facilitate the implementation and extensions of the agreements already in place between EUMETSAT and the China Meteorological Administration and the National Satellite Ocean Application Service."[25]

There is a possibility that China will offer the only available early morning sounding data for global weather modeling in the 2024 to 2027 timeframe. This data has a positive impact on the accuracy of civilian and military numerical weather prediction models. As such, it is likely this data will find its way into products used by U.S. civilian and military forecasters. The FY16 National Defense Authorization Act (NDAA) prohibits DOD reliance on, but not use of, "space-based weather data provided by the Government of China, the Government of the Russian Federation, or an entity owned or controlled by either such government for national security purposes."[26] NOAA is required to secure DOC approval for use of data from a Chinese system.

Key questions related to DOD's continued reliance on civil systems in the context of the escalating threats to space systems include:

- Does DOD understand the resilience of the civil SBEM systems upon which it plans to rely in peacetime and under combat conditions?

- Has DOD assessed the potential benefits of *using* space-based weather data from China and Russia (currently allowed by policy) while not realizing the risk of becoming *reliant* on space-based weather data from those nations (currently prohibited by policy) to satisfy warfighter requirements?

- How much should DOD depend on civil and commercial SBEM systems to meet critical needs ─ especially where the priority for certain space-based observations is not aligned?

- Should DOD consider extending its umbrella of space asset defense/protection to domestic or even foreign civil SBEM assets as alluded to in the recently published USSF Space Power Doctrine?[27]

- Should national security resiliency requirements be applied to NOAA satellites upon which DOD is critically reliant?

- Given DOD's reliance on international capabilities in its SBEM family of systems, should DOD have a greater role in international forums such as Coordination Group for Meteorological Satellites?

- Is there a risk that optimal performance of U.S. weather prediction models could unintentionally lead to a reliance on data from China satellites?

Hurdles for DOD's Pursuit of Next Generation SBEM Capabilities

DOD's Priority SBEM Requirements

Following the divergence of NPOESS into separate DOC and DOD SBEM programs in 2010, USAF initiated the Defense Weather Satellite System (DWSS) program to replace DMSP. The DWSS program was cancelled in 2012 because it was considered early-to-need with unsustainable costs.[28] Subsequently, DOD conducted an analysis of alternatives to determine updated and prioritized requirements for DOD SBEM capabilities. In September 2014, the analysis of alternatives (AoA) results led to a Joint Requirements Oversight Council-approved set of 12 high-priority SBEM requirements[29] and a DOD strategy to meet those requirements (Table 2). Table 2 entries highlighted in yellow reflect needs that USAF determined would require a material solution based on the finding that civil, commercial satellite weather data, and international partnerships would not sufficiently satisfy specific METOC needs, as required by the FY15 NDAA.[30]

Table 2: Prioritized DOD MEOTC Needs

Priority	Joint METOC Needs
1	Cloud Characterization
2	Theater Weather Imagery
3	Ocean Surface Vector Winds
4	Ionospheric Density
5	Snow Depth
6	Soil Moisture
7	Equatorial Ionospheric Scintillation
8	Tropical Cyclone Intensity
9	Sea Ice Characterization
10	Auroral Characterization
11	Energetic Charged Particles
12	Electric Field

Entries in shaded rows reflect needs that DOD determined would require a material solution. (Source: JROCM 092-14, September 3, 2014)

DOD-Civil Agency Coordination for SBEM Mission

In the GAO-19-458T report, GAO described three DOD challenges relevant to SBEM: growing threats to satellites, implementing leadership changes, and having the right resources and know-how.[31] In the same report, the GAO reported that past studies and reviews examining the leadership, organization, and management of national security space found [32]:

- There is no entity below the president charged to integrate SBEM programs across the government.
- Responsibilities for acquiring space systems are diffused across DOD organizations as well as the intelligence community and civil agencies, such as NASA and NOAA, who rely on these systems.
- This lack of ongoing, interagency coordination has led to delays in fielding systems. No one person or organization is held accountable for balancing governmentwide needs against wants, resolving conflicts and ensuring coordination among the many organizations involved with space acquisitions, and ensuring that resources are directed where they are most needed.[33]

USSF could address these challenges for all DOD mission areas including SBEM. However, the SBEM mission area encompasses more than a dozen U.S. government and international agencies and addresses needs that are broader than purely military interests, which is not within USSF's charter. Historically, DOD has utilized a variety of organizational constructs to provide cross-cutting SBEM coordination. Some were in place for many years while others, especially in the past 10 years, have been short-lived, leading to inconsistent coordination and results.

DOD's organizational structure with respect to the SBEM mission is disaggregated. Congress recognized and attempted to address this challenge in the 2017 National Defense Authorization Act. In that Act, Congress directed the secretary of defense and the NOAA administrator to jointly establish mechanisms to: collaborate and coordinate in defining roles and responsibilities to carry out SBEM activities and plan for future nongovernmental SBEM capabilities.[34] In response, DOD and NOAA provided a report to congressional subcommittees which included a list of mechanisms used to carry out joint SBEM activities. The mechanisms included assigning service (USAF and USN) deputies to NOAA, joint working groups, memoranda of agreement, joint participation in committees, and DOD leveraging NOAA international partners.[35] Table 3 provides a snapshot of congressional scrutiny on DOD's SBEM portfolio since 2015.

A previous structural approach for DOD was to have the secretary of the Air Force wear the "hat" of the principal DOD space advisor (PDSA). The PDSA staff served as the single SBEM advocate with responsibility to coordinate with NOAA on behalf of all DOD equities with a focus on policy and requirements. For the relatively short amount of time it existed, this office was effective at promoting DOD-NOAA SBEM mission collaboration. In early 2018, the PDSA function was terminated and the duties, responsibilities, personnel, and resources of the office were transferred to the deputy secretary of defense on an interim basis.

Although DOD and NOAA have the most well-known operational SBEM needs, other government organizations have SBEM needs as well (for example, NASA, the Intelligence Community, and others). This creates challenges resolving the problems highlighted by the GAO. However, it also suggests questions to address in national and DOD forums, and offers an opportunity to discuss a potential framework for a whole-of-government SBEM enterprise integration approach to address the GAO concerns:

- To what extent will future budget pressures amplify DOD reliance on civil capabilities to meet warfighter and other national security needs?
- What will be the roles of the following DOD offices/organizations in addressing DOD SBEM activities, including collaboration with NOAA and international partners?
  - Space Acquisition Council
  - Deputy Assistant Secretary of Defense for Space Policy
  - Assistant Secretary of the Air Force for Acquisition, Technology & Logistics
  - Assistant Secretary of the Air Force for Acquisition and Integration
  - Space acquisition organizations including the Space Systems Command and Space Development Agency
  - Air Force Weather, Naval Meteorology and Oceanography Command, and other Joint METOC organizations
- Could existing entities that operate within the U.S. government serve as natural forums to facilitate whole-of-government, SBEM planning?

In the next section, we present a notional framework for six separate dimensions relevant to SBEM policy at the department and agency levels.

Table 3: Congressional Scrutiny on DOD SBEM	
Key Document	**Direction**
FY 2015 NDAA, Section 1812	Directs DOD to develop plan for meeting JROC METOC requirements. Directs GAO to review DOD SBEM analysis of alternatives (AoA).
GAO Report (GAO-16-252R, March 2016)	Recommended that SECDEF ensure the leads of future SBEM planning efforts establish formal mechanisms for NOAA collaboration that specify roles and responsibilities.
AF Report to Congressional Committee, August 2016	Delivered DOD plan to meet JROC METOC requirements through civil and commercial weather data, and international partnerships.
GAO Report, GAO-16-769T, July 2016	Recommended that DOD establish formal mechanisms for coordination with NOAA for future SBEM system acquisitions.
FY 2017 NDAA, Section 1607	Required DOD and NOAA to jointly establish mechanisms for collaboration and cooperation in SBEM roles and responsibilities.
AF Report to Congressional Committees, May 2017	Plan to address DOD requirements for cloud characterization and theater weather imagery.
AF Report to Congressional Committees, September 2017	Delivered plan for establishing joint mechanisms between NOAA and DOD for defining SBEM roles and responsibilities.
180-day Congressional Task, Consolidate Appropriations Act, 2020 (Public Law 116-93)	Directed SECAF to provide a strategy, including proposed acquisition plans, estimated cost, and schedule of key milestones, for an architecture to meet JROC requirements.

The completion of the DOD SBEM AoA in 2014 spurred over five years of enhanced congressional stakeholder scrutiny of DOD SBEM acquisition activities. That scrutiny resulted in two NDAAs (FY15 and FY17) addressing required SBEM actions, three DOD Reports to Congress providing responses to those requirements, three Government Accounting Office (GAO) reports describing challenges and successes with SBEM system development, and DOD and NOAA executing a Memorandum of Agreement (MOA) on SBEM Data Collection and Sharing (Table 2). Over time, DOD and NOAA demonstrated substantial progress on SBEM data collection and sharing because of this activity. In a 2019 report, the GAO (GAO-19-157SP, March 2019, pg. 13) found that DOD and NOAA "have made significant progress in establishing and implementing plans to mitigate potential gaps in weather satellite data." The agreement between NOAA and DOD to move a repurposed NOAA GOES satellite over the Indian Ocean for DOD use (EWS-G, described above) is a major success story of that MOA. The resiliency and defense of the civil assets being utilized by the military and national security community did not appear to factor into the evaluation by Congress or within the executive branch. In July 2020, Department of Air Force published a report describing its strategy to address the 12 validated JROC requirements previously prioritized for a material solution. This report fulfilled the congressional direction in PL 116-93 referenced in the table.

From Enterprise Integration to SBEM Policy

The SBEM element of the 2010 National Space Policy was relatively limited in scope and focused on LEO assets. The 2020 National Space Policy expanded top-level guidance to a broader approach calling on the secretary of commerce, secretary of defense, NASA administrator, and heads of other appropriate agencies to work together to address next generation space systems planning, ground system architectures for operations, data sharing, international engagement, and commercial data purchases. Figure 2 describes a framework of attributes that could address SBEM-related policy from a whole-of-government perspective and facilitate assessment of risks associated with the reliance on civil systems to meet NSS requirements. The six attributes include: (I) Nature of the nation's SBEM architecture ranging from independent civil and military constellations to an interdependent, whole-of-nation approach; (II) Scope with respect to the division of roles and responsibilities between NOAA and DOD ranging from a broad, nonprescriptive to highly prescriptive policy that defines roles and responsibilities for NOAA and DOD across all orbital regimes (LEO, GEO, etc.); (III) Treatment of operational civil SBEM assets as critical NSS infrastructure (or not) including consideration of cyber-resiliency and other factors; (IV) Architecture characteristics ranging from traditional, large, complex integrated missions to smaller, distributed, resilient missions; (V) Pursuit of commercial services; and (VI) The extent of DOD reliance on data from friendly and unfriendly international sources versus a purely organic, U.S. assets.

Many of these attributes are actively being discussed today across the government. The cyber resiliency of space-based assets (attribute III) is the topic of the recently released Space Policy Directive-5, Cybersecurity Principles for Space Systems.[36] While NOAA space systems comply with civil directives for cyber and other security measures, they are not held to the more stringent protection standards applied to other national security space (NSS) assets. Policy considerations include whether civil systems that represent critical national security infrastructure should benefit from DOD's defensive space capabilities, exhibit resilience under adversarial operating conditions, and be directed to comply with cyber-protection standards equivalent to NSS assets. Closely related to resilience is attribute V (Figure 2). Both DOD and NOAA are considering disaggregated architectures for select missions, where it makes sense, which is inherently associated with increased resilience. The final element of the framework involves defining U.S. objectives with respect to international SBEM partnerships (attribute VI, Figure 2).

In summary, the proposed policy framework establishes attributes to address in a robust SBEM policy dialogue. We anticipate that these policy questions could be informed by outcomes of a multiagency coordination process described in the next section of the paper. The attributes in Figure 2 are illustrated as a sliding scale with the left and right positions considered to be extreme, opposite positions. They are sufficiently independent to envelop the needed policy dimensions but are not necessarily mutually exclusive. Note that this paper neither characterizes the current state with respect to each attribute nor advocates for the future direction of agency- and national-level policy. The intent is to outline the spectrum of options. In the context of this framework, discussions focused on the key questions posed throughout the paper would help inform the revision of national civil space policy and its flow down into future DOD and NOAA (and other) SBEM plans.

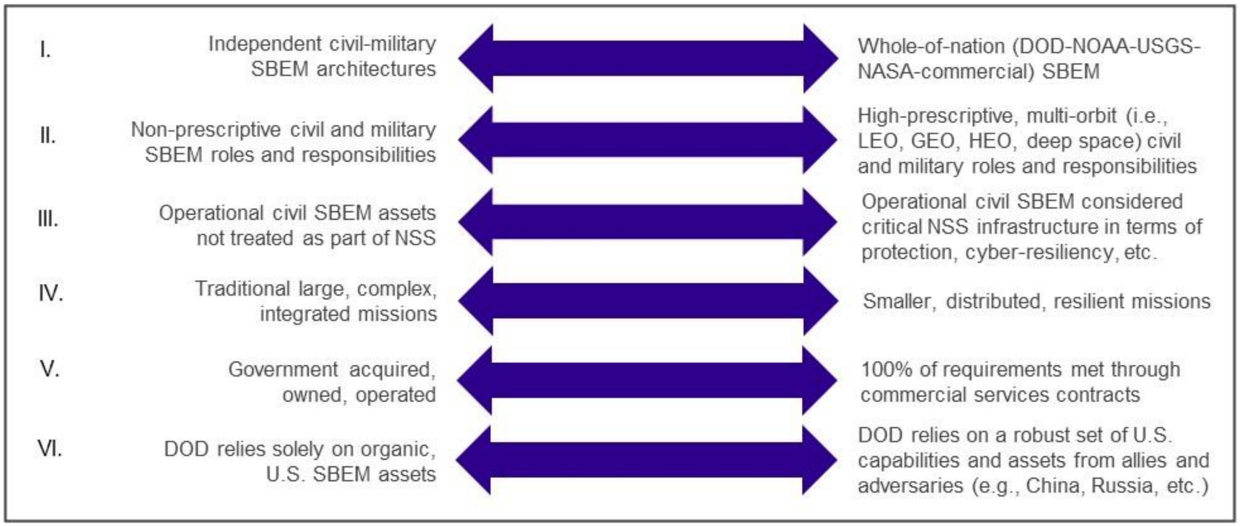


Figure 2: Proposed framework of policy attributes to consider at the national and DOD levels. Note that "whole-of-nation" is whole-of-government + commercial + academia.

A Conceptual Framework for Whole-of-Government SBEM Integration

Policy guidance at the White House, department level, and agency level addressing the dimensions described in Figure 2 can be informed by and set the stage for whole-of-government SBEM coordination or integration. However, the independence of U.S. government agencies with respect to mission essential functions, statutory responsibilities, budget, executive direction, process-driven timelines, and congressional oversight does not naturally facilitate integrated, whole-of-government programming, planning, and execution. The SBEM mission-area nevertheless presents a compelling business case for multiagency planning on a grand scale. In order to advance the SBEM dialogue, a conceptual framework for whole-of-government coordination/integration is described. Here we define an *enterprise* as all organizations (e.g., government, commercial, academic, and international) contributing to common activities.

At a top level, enterprise integration is a technical field of enterprise architecture that addresses challenges such as system interconnection, electronic data interchange, product data exchange, and distributed computing environments.[37] It is also a concept in enterprise engineering focused on enabling communication between people (organizations), machines, and computers and their efficient cooperation and coordination.[38] For this discussion, we adopt the concept of enterprise integration as a structured process, or framework (Figure 3) to coordinate across U.S. government stakeholders with an objective to field and sustain a system of SBEM systems to deliver critical national benefits. We describe and apply the framework not to suggest it is the solution for the nation, but as an illustration of how integration could be achieved within the existing interagency construct for the SBEM mission area. The utility of the framework is not narrowly limited to the SBEM mission area.

The integration framework (Figure 3) has four levels. Level 1 begins with analysis by individual SBEM mission organizations performing a normal cyclical review of mission needs (current and developing), assessing current capabilities to meet those needs, identifying gaps, prioritizing those gaps, and developing mission architecture plans/changes to address gaps. Each SBEM organization performs this review based on needs from multiple sources—some specifically given to an organization based on its mission and stated in executive direction or law (e.g., NDAA for DOD SBEM mission), and others that may be part of a national plan or strategy (e.g., National Space Weather Strategy, 2019 National Plan for Civil Earth Observations, FY22 White House Office of Management and Budget/OSTP Research and Development Priorities, etc.). Framework levels 2, 3, and 4 are performed collaboratively by the entities that participated in the Level 1 analysis.

Level 2 addresses horizontal integration of inputs across the multiple SBEM organizations—comparing the total capabilities of all SBEM organizations against "whole-of-government" needs in observational capability, data and information, and/or services. The anticipated result is a list of enterprise gaps in SBEM-related capabilities in the full context of national SBEM needs. Level 3 vertically integrates the Level 2-identified gaps, evaluates them for potential SBEM vulnerabilities, and assesses enterprise SBEM resiliency and risks. Level 4 of the framework determines the viability and path of SBEM enterprise change processes.

A key question is: where within the structure of the government can the Level 2 through 4 coordination occur? There are two White House-level bodies whose charters might be extended to at least facilitate a dialogue. United States Group on Earth Observations (USGEO) and Interagency Council for Advancing Meteorological Services (ICAMS) are White House-level bodies chartered to perform aspects of SBEM-related enterprise integration (see appendix). Their charters do not explicitly

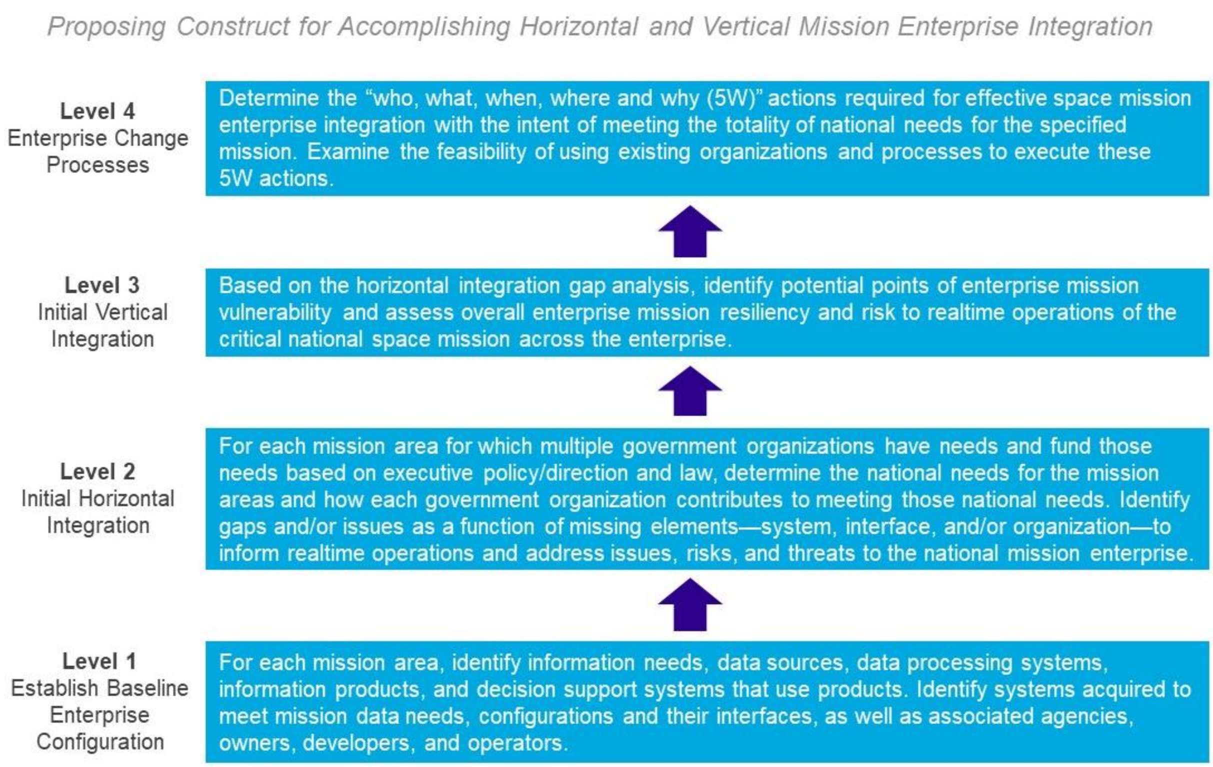


Figure 3: Notional space mission enterprise integration framework.

charge USGEO or ICAMS to facilitate SBEM integration at a system of systems architectural level across the U.S. government. However, these organizations could facilitate discussions to catalyze an integration effort.

With a formalized conceptual approach to achieving integrated outcomes, the U.S. could move toward a robust, whole-of-government approach to SBEM. Potential outcomes include decadal strategic plans for enhancing SBEM, strengthened partnerships with nongovernment sectors and international partners, and coordinated interagency messaging to inform senior policymakers of SBEM capability needs, vulnerabilities, and resiliency. Another objective could be refined strategic messaging of SBEM benefits related to national and economic security as well as societal factors such as public safety. SBEM enterprise integration across the U.S. government must be enabled by national and agency-level policy.

Conclusions

The combined space-based capabilities of NOAA and DOD represent critical national security infrastructure. NOAA satisfies its priority requirements through a civil space architecture while DOD relies on a joint military-civil satellite ecosystem to satisfy warfighter requirements. The use of civil satellites is not unique to the SBEM mission-area. However, the scope of DOD's reliance on a civil-military-international family of systems for SBEM exceeds any other mission area. NOAA and DOD sit at pivot points with an opportunity to plan the next generation of environmental satellites that will comprise the combined U.S. architecture out to 2040 and beyond.

Given DOD's dependence on non-military assets, it is important to assess the national security risks associated with reliance on civil SBEM assets that might not satisfy national security resilience requirements under adversarial operating conditions. Challenges for the U.S. in the SBEM mission-area are not limited to resilience. China's muscular initiatives in the SBEM mission-area threaten U.S. preeminence and introduce the risk of future reliance by global weather centers for operational forecast modeling on potentially high-quality data from an adversary.

Stakeholders in the SBEM mission-area span at least 18 U.S. government entities. In order to illuminate opportunities for multi-agency integration, this paper presents a conceptual approach to enterprise SBEM integration and connects it to a robust set of enabling national and agency-level policy attributes. Macro-level choices range from independence between the space-faring agencies, with expectation to create and capitalize on leveraging opportunities, to full scale joint mission planning based on a whole-of-nation strategy. Across the broader U.S. enterprise, existing entities within the government (i.e., USGEO and ICAMS) could be utilized to advance the nation toward an enterprise approach to SBEM to address needs ranging from operational forecasting to long-term climate monitoring. The results of such an integrated approach hold the promise of addressing national security imperatives, NOAA's primary mission essential functions, and the broad needs of the nation for decades to come.

Acknowledgments

The authors would like to express their gratitude to Rebecca Reesman, Michael Van Woert, John Maguire, Jamie Morin, Martin Whelan, Robert Winokur, Donald Boucher, Jennifer Clapp, LeRoy Collins, John Haas, Richard Heidner, Orlando Figueroa, and Charles Wooldridge for their helpful reviews and comments.

Appendix – SBEM, A Whole-of-Government Mission Area

Although this paper focuses on DOD, NOAA and NASA SBEM opportunities and challenges, other federal agencies rely heavily on DOD and NOAA SBEM data and augment that support with their own operations or research and development in SBEM technology. This makes SBEM very much a whole-of-government mission. Across all agencies, the federal government invests more than $3 billion in civil Earth observations and data to ensure national security, enhance public safety and infrastructure protection, promote quality of life, strengthen the economy, and fulfill other agency missions.[39]

Other federal agencies that prominently figure into the whole-of-government SBEM equation (i.e., SBEM "enterprise") include the Department of Agriculture (USDA), Department of Energy (DOE), Department of Homeland Security (DHS), Department of Interior (DOI), and Environmental Protection Agency (EPA). USDA works closely with NOAA and NASA to field integrated capabilities to identify fires and to forecast fire weather conditions.[40] DOE collaborates with NASA to monitor atmospheric radiation and to collect data to support decisionmaking and policymaking related to space nuclear power and propulsion, space situational awareness, space weather, and climate change.[41] Teaming with DOD, DHS's recent SBEM initiative, called Polar Scout, supports the U.S. Coast Guard's (USCG) mission to ensure safe, secure, and environmentally responsible maritime activity in U.S. Arctic waters.[42] The DOI's U.S. Geological Survey (USGS) has continuously operated Landsat satellites since 1972. These satellites acquire space-based images of the Earth's land surface, providing uninterrupted data to help land managers and policymakers make informed decisions about our natural resources and the environment. Landsat data informs good decisions in many disciplines, especially human health, agriculture, climate, energy, fire, natural disasters, urban growth, water management, ecosystems and biodiversity, and forest management.[43] Currently, USGS and NASA are teaming up to build the next Landsat mission, Landsat 9, which is scheduled for launch in mid-2021. EPA scientists are collaborating with NASA, the Smithsonian Astrophysical Observatory (SAO) and NOAA on a project that will use satellites to examine air quality across North America. The Tropospheric Emissions Monitoring of Pollution (TEMPO) satellite, part of NASA's Earth Venture Instrument program, is scheduled for launch in 2022 to monitor air quality during the daylight hours in geostationary orbit.[44]

Two interagency organizations work from a whole-of-government perspective across the environmental enterprise including SBEM to achieve a level of what we refer to as enterprise integration. They are The United States Group on Earth Observations (USGEO) and the Interagency Council for Advancing Meteorological Services (ICAMS).

USGEO is a chartered subcommittee of the National Science and Technology Council (NSTC) Committee on Environment.[45] USGEO's purpose is to plan, and coordinate federal Earth observations, research, and activities; foster improved Earth system data management and interoperability; identify high priority user needs for Earth observations data; and engage international stakeholders by formulating the United States' position for, and coordinating U.S. participation in, the intergovernmental Group on Earth Observations (GEO). USGEO has 15 members, including:

- Five departments (Agriculture, Defense, Energy, State, and Transportation)

- Eight agencies (Environmental Protection Agency (EPA), NASA, National Institutes of Health (NIH), National Institute of Standards and Technology (NIST), NOAA, NSF, Smithsonian Institution, and U.S. Geological Survey (USGS)

- Two organizations within the Executive Office of the President, the Office of Management and Budget (OMB) and Office of Science and Technology Policy (OSTP)

Although the focus of USGEO is on civil Earth observations, DOD has been active in USGEO since its formation in 2003. USGEO takes an enterprise approach to its activities, defining the Earth Observations Enterprise as the multi-sector enterprise consisting of federal agencies; state, local, tribal, and territorial governments; world-leading colleges and universities; private industries; non-profit organizations; and federal and national laboratories. USGEO works to achieve its purposes through coordination of the acquisition, analysis, dissemination, and use of Earth observations; the operation of enabling infrastructure; sustaining and advancing the creation of data and information products; maintaining routine uses; and developing innovative applications for societal, environmental, and economic progress. Lastly, USGEO uses its enterprise approach to open opportunities for partnerships for the provisioning and analysis of Earth observations. Over the course of its 17 years of existence, USGEO has represented a coalition of the willing focused on the data and information resulting from observation systems, including satellites.

ICAMS was chartered on July 31, 2020, having been formed as a result of the 2017 Weather Research and Forecasting Innovation Act (Public Law 115-25, Title IV, sec 402, 15 USC) which required OSTP to form such an interagency committee.[46] Under the charter, ICAMS will lead the annual development of an interagency budget review of programs supporting meteorological services and supporting research and annual implementation plans. DOD will participate to the limits imposed by the Federal Acquisition Regulations. ICAMS is a multi-agency Executive Branch activity, served by an administrative organization (Interagency Meteorological Coordination Office—IMCO) and four subcommittees focusing on observational systems; cyber, facilities and infrastructure; services; and research and innovation.

The ICAMS co-chairs are the OSTP Director and the Undersecretary of Commerce for Oceans and Atmospheres (NOAA Administrator). ICAMS members include the Executive Office of the President (OMB and OSTP), nine departments (Agriculture, Commerce, Defense, Energy, Health and Human Services, Homeland Security, Interior, State, and Transportation), and five agencies (EPA, NASA, Nuclear Regulatory Commission, NSF, and National Transportation and Safety Board). ICAMS' main goal is for the "United States to lead the world in meteorological services via an Earth system approach, providing societal benefits with information spanning local weather to global climate." The charter is specific in stating that ICAMS does not represent budget authorities, does not imply any resource commitments by member agencies, and does not make policy. However, ICAMS can inform policy, coordinate for relevant policies and practices across agencies, and foster engagement with other federal coordination organizations, such as the NSTC to meet the goals articulated by the council.

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