

How to Make Disaggregation Work

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And so resilience is made up of a number of things. Disaggregation could be a big piece of that, because right now we have a very small number of satellites on orbit and our adversaries know exactly where they are.

—Gen John Hyten
Commander, Air Force Space Command

Evolutionary, Not Revolutionary Disaggregation

The concept of disaggregation refers to a means of creating resiliency by spreading capabilities across diverse platforms, including hosted payloads, smaller satellites, and tactical and strategic capabilities. As commercialization continues to usurp more of the space-platform ecosystem, disaggregation of many systems becomes evolutionary rather than revolutionary, allowing government to take advantage of a new architectural paradigm.

Space: Congested, Contested, Competitive, and Commercialized

In the new millennium, activities in space are rapidly on the rise. The January 2011 *National Security Space Strategy* highlighted that the space environment is increasingly *congested*, *contested*, and *competitive*.¹ At the end of 2012, over 1,000 operating satellites were on orbit, contributing to a global \$189.5 billion telecommunications and space industry. Since 2001 satellite industry revenues have nearly tripled, averaging an annual growth of 10 percent. Communication is the primary function of over half the operational satellites, and of those, 38 percent are of a commercial nature.² Today, more than 50 countries are represented by at least one satellite orbiting the earth, and the United States leads the pack. With this rapid growth in mind, it seems fitting that an additional descriptor be attached to the space environment: commercialization.

Additional examples of this rapid commercialization of the space domain include NASA's successful strategy to resupply the International Space Station through commercial launch service contracts to SpaceX and Orbital Sciences Corporation, which

have demonstrated the capability to launch, dock with the space station, and deliver critical supplies and cargo. Both companies are past the challenging developmental phase and are now moving on to the lucrative launch-service phase of these contracts. Other examples of the rapid commercialization of the space domain include nascent efforts by venture-capital-funded companies such as SkyBox (Google) and PlanetLabs to dramatically reduce cost and timelines to deploy Earth-imaging satellites. Other companies such as Virgin Galactic and Bigelow Aerospace seek to serve the adventure tourism market with a promise of the ultimate adventure—vacations to outer space!

As this industry has evolved over the past 50 years, protection of these assets has taken second place to the spirit of exploration and pursuit of commercial gain. China's successful antisatellite test in 2007 and a series of subsequent tests have proven that US satellites are at risk. Threats to our satellites, either physical or virtual, could leave the United States vulnerable to more serious security threats and wreak havoc with our economy.

A Thoughtful Approach to Disaggregation: Three-Layered Space Architecture

This approach to disaggregation proposes a mission-by-mission process within the context of the threat and risk environment. The Three-Layered Space Architecture model is composed of (1) commercial commodities; (2) resilient tactical components; and (3) strategic space (see the figure below).

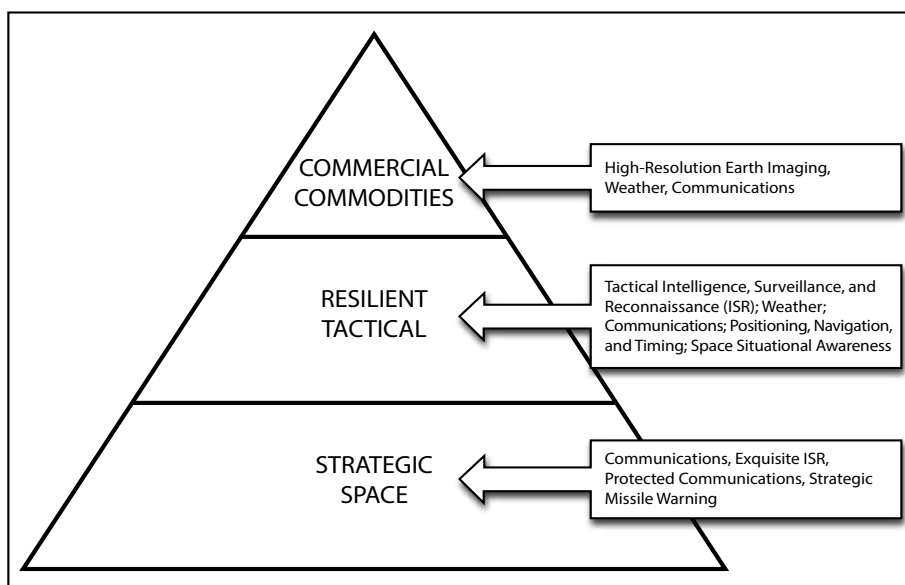


Figure. Three-layered space architecture model. A disaggregated architecture (1) invigorates the space industrial sector, (2) increases the resiliency of the national security space architecture, and (3) enhances the persistence of intelligence, surveillance, and reconnaissance capabilities by means of larger numbers of satellites.

Commercial Commodities Layer

The most dynamic of the three elements—the commercial commodities layer (CCL)—is the most rapidly changing and least expensive since costs continue to decline due to the infusion of new business models and technology. The Department of Defense (DOD) can simply buy capabilities by the picture, bit, or minute. Potentially, it is also the most vulnerable layer because these commercial systems typically will present soft targets to cyber or physical attacks, but through disaggregation and diversity, they may buy back resilience. One anticipates that this layer will grow to provide as much as 80 percent of the total Earth imaging, weather sensing, and communications capabilities used by the DOD—and will feature increased resilience and persistence.

Resilient Tactical Layer

The resilient tactical layer (RTL) will consist of a critical number of tactical intelligence, surveillance, and reconnaissance (ISR) satellites, weather satellites, and communications satellites required to sustain military operations in times of global crisis when commercial space systems may be denied, degraded, or destroyed. This layer will also include capabilities not conducive to development and operation by commercial companies when a profit motive may prove negligible (e.g., signals intelligence systems, space situational awareness systems, etc.). These systems will be smaller and lower in cost than today's national security satellite systems; thus, they can also be used to rapidly reconstitute capabilities that may be lost in the other two layers. An RTL is also beneficial because it is much easier and less costly to use these systems to reconstitute lost space capabilities of a critical nature. These smaller satellites can be launched on less sizable rockets that are cheaper, easier to use, and faster to manufacture and deploy.

Strategic Space Layer

Included in the strategic space layer (SSL) are some of the nation's most advanced and sophisticated space capabilities, such as exquisite ISR, strategic nuclear communications command and control, and strategic missile warning. These technologies are not available in the commercial sector, and in many cases they are highly classified to protect against their dissemination. These systems can be simplified by removing payloads and missions not necessary for their primary functions. Such capabilities will be absorbed by either the CCL or RTL. For example, today the space-based infrared satellites (SBIRS) host payloads for four different functions: strategic missile warning, missile defense, battlespace awareness, and tactical intelligence. The battlespace awareness and tactical intelligence missions could be off-loaded to other less complex satellites in the RTL, reducing the complexity, cost, and development time of the SBIRS satellites.

Department of Defense Space-Based Weather Example: Less Costly, More Diverse and Rapid, More Persistent and Resilient

The centerpiece of DOD space-based weather architecture has been the Defense Meteorological Satellite Program (DMSP), which is coming to an end. In the CCL, a budding industry can offer such a service (e.g., PlanetIQ and GeoMetWatch) for requirements such as cloud imaging and profiles of atmospheric parameters (both tropospheric and ionospheric) via Global Positioning System (GPS) radio occultation. The DOD is likely to explore such commercial options with much more rigor. As these companies develop a strong business case in which the DOD is but one customer, the price point for the service will be attractive, and it will prove a valuable addition to capabilities acquired by systems in the RTL and SSL. In the RTL, the Jet Propulsion Laboratory is developing a Compact Ocean Wind Vector Radiometer payload for potential use by the operationally responsive space modular space vehicle for inexpensive demonstration to meet a need from the Joint Requirements Oversight Council. The Small Cloud Imager is a smaller, less complex satellite made by industry with a mass of less than 50 kilograms and a total mission cost of less than \$80 million. Currently, the DMSP is the only DOD weather mission in the SSL, but services could be augmented by adding the National Oceanic and Atmospheric Administration's polar-orbiting operational environmental satellites; the Joint Polar Satellite System; and the European Organisation for the Exploitation of Meteorological Satellites—and by extending key requirements through public-public partnerships.

Trend: A Commercial Market Capable of Providing Most Future Requirements

The commercial small space market, which has reached a growth inflection point, could supply 80 percent of future requirements in a disaggregated architecture. Small satellites—microsats in particular—are in the midst of a fourfold growth spurt with longer-term growth implications. Launch-market technical and business innovations are close to achieving dramatic reductions in launch costs—the primary barrier to entry for space enterprise—and may be realized in the marketplace before 2020. Together, these emerging conditions are setting the stage for technological and economic revolution in the space business. According to recent analysis, the following key emerging trends will continue to redefine the satellite market, remaking it into a “network agnostic” and “device agnostic” crossroad for data distribution:³

- The market is rapidly segmenting between large-complex systems and small, lower-cost, lower-risk, and adequately functional systems.
- The global satellite market is showing emerging fractures as nontraditional content providers chip away at global markets.⁴
- Lower-cost satellites made with off-the-shelf components are driving capabilities up and costs down. Reducing satellite mass and employing commercially viable components and manufacturing processes create appropriate governmental

capabilities for 80 to 90 percent less than costs commonly attributed to current satellite fleets.

- Launch costs are declining in response to technical and business innovation.
- Demand for commercial satellites able to provide imaging, measurement, and signature observation capabilities is increasing as the use of commercial satellite imagery and data continues to supplement or replace less efficient means of discovery, measurement, and verification.
- Cloud computing and mobile wireless applications continue to create new innovations, spawning new means for utilization, new market demand, new deployed capabilities, new users, and new data sets.
- New investment in the small satellite market is on target to approach the billion-dollar mark by 2016. Investors are attracted to the growing industrial and consumer-level demands for data and related services, such as small imaging and sensing satellite market models.
- Small satellite technology models are merging with mobile wireless M2M (machine to machine) architectures and should be able to provide additional persistent and ad hoc capacity for supporting text messaging, payment processing, mobile shipment tracking, crop and disaster imaging, parking telemetry, remote asset analysis, remote diagnostics, and health-care applications such as remote patient monitoring, among many others.
- Low-cost imaging plus low-cost cloud computing and mobile wireless distribution will allow users new real-time data streams that they can use to further understand, promote, and manage critical functions such as energy infrastructure management, shopping patterns, crop yield projections, shipping management, and insurance underwriting.

Low-cost imaging satellites are on track to take “precision agriculture” to the next level by advancing remote management and diagnostics, further improving efficiency, crop yield, and return on investment. This capability will build upon the 30 percent productivity improvement to crop yields delivered by the GPS over the past decades.

Continued Investment for the Disaggregated Space Architecture Vision 2025

Pushing the cost and technological envelope is not without risk. However, such peril can be vetted and metered by maintaining an entry point for technology refreshment, operational prototyping, and replenishment of urgent-need capabilities. Congress has already authorized these functions through the Operationally Responsive Space Office.⁵ Continued advances can be made through investments phased over a three-to-four-year time frame with a cost of approximately \$50–60 million per year.

Commercial companies are beginning to disrupt space, just as technological innovations have disrupted media and communications. Today one can invest in the common enabling technologies and processes necessary to realize, for national security,

the two new layers proposed in this three-layered space architecture: the RTL and CCL. We recommend that these investments be coordinated by a single DOD program to leverage investments across the DOD, intelligence community, and the civil and commercial space sectors. Finally, we propose that an independent board of advisers be assembled to review these investment plans, execution strategies, and organizing constructs.

Three-Layered Architecture: Resiliency, Affordability, and Technology Refreshment

Creating an architecture that is resilient, affordable, and expandable need not be an “all or nothing” approach to disaggregation but a “mission by mission” approach. As technological prowess grows and technology life cycles shorten, opportunities for more capable and lower-cost architectures become possible through infusing smaller satellites. As the cost of smaller satellites continues to decrease and as they become able to pack advanced technologies into more compact payloads, they offer augmentation and replacement for existing architectures and complementary coexistence. 🌟

Notes

1. Department of Defense and Office of the Director of National Intelligence, *National Security Space Strategy: Unclassified Summary* (Washington, DC: Department of Defense and Office of the Director of National Intelligence, January 2011), 1, http://www.defense.gov/Portals/1/features/2011/0111_nsss/docs/NationalSecuritySpaceStrategyUnclassifiedSummary_Jan2011.pdf.
2. Satellite Industry Association, “State of the Industry Report” (Washington, DC: Satellite Industry Association, 2014).
3. Chris Quilty, Raymond James Financial, “Satellite Industry & Wall Street” (presentation at World Space Risk Forum, Dubai, 2014), Trends Digest Database, http://worldspaceriskforum.com/2014/wp-content/uploads/2014/05/2A_WHERE-THE-CAPITAL-COMES-FROM_QUILTY.pdf; and [Maureen Rhemann], “Trend Watch: Five Reasons Why Smallsats Are about to Disrupt Telecom, Space, and Anything Else They Touch,” *Trends Digest*, [January 2015], <http://trendsdigest.com/>.
4. See Scott Hubbard, “Roundtable Discussion: Growing the Future of Commercial Space,” *New Space Journal* 1, no. 1 (March 2013): 3–9, <http://online.liebertpub.com/doi/pdfplus/10.1089/space.2013.1501>.
5. See John Warner National Defense Authorization Act for Fiscal Year 2007, Public Law 109-364, 109th Cong., 17 October 2006, sec. 913, Operationally Responsive Space, <http://www.gpo.gov/fdsys/pkg/PLAW-109publ364/pdf/PLAW-109publ364.pdf>.



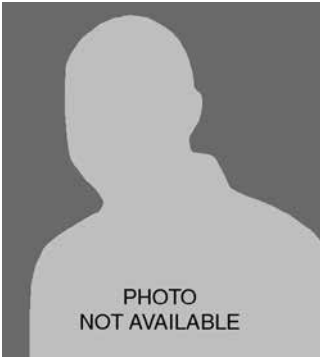
Dr. Peter Wegner

Dr. Wegner (BS, University of Arizona; MS, Stanford University; PhD, University of Wyoming) is the chief technology officer of Spaceflight Industries. He has more than 20 years of experience in the research, development, design, and operations of advanced spacecraft, rockets, and ground control systems. Prior to joining Spaceflight Industries, he held a director-level position with USU / Space Dynamics Lab where he led investments in new technologies and systems to solve some of the nation's most critical emerging space problems. Dr. Wegner was also a founding member and ultimately the director of the Department of Defense's (DOD) Operationally Responsive Space Office at Kirtland AFB, New Mexico, where he directed a budget in excess of \$120 million per year and a staff of over 60 persons chartered with the responsibility for implementing a national strategy to develop new and innovative techniques to design, build, test, and operate space systems to support DOD missions. This strategy included developing the ability to rapidly reconstitute and augment critical space capabilities in a time of crisis. Dr. Wegner has also held positions as the technical adviser to Air Force Space Command's Directorate of Requirements and as a research engineer with the Air Force Research Laboratory's Space Vehicles Directorate where he developed many key innovations such as the Evolved Expendable Launch Vehicle's Secondary Payload Adapter ("ESPA Ring"), which has helped open the door for many small satellite programs to find a ride into space. Dr. Wegner has been a lead inventor and coinventor on five US patents.



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Dr. Adang (BS, Purdue University; MPM, Saint Louis University; PhD, University of Arizona) is the senior technical adviser (The Aerospace Corporation) in the Operationally Responsive Space (ORS) Office at Kirtland AFB, New Mexico. In this position, he is responsible for providing technical leadership and strategic engagement support to the ORS Office as it develops and provides responsive space capabilities for joint force commanders and other users. Dr. Adang has more than 40 years of experience in atmospheric sciences, as well as in aircraft and space vehicle development, testing, and operations. Prior to supporting the ORS Office, he served a two-year federal appointment with the National Oceanic and Atmospheric Administration (NOAA) in a Senior Executive Service position as the NOAA technical director for integrated observations and data management. He joined The Aerospace Corporation in October 2000 as a senior project engineer supporting the National Reconnaissance Office (NRO). In March 2002, he established the Silver Spring Program Office supporting the NOAA Satellite and Information Service and served as that office's systems director. Prior to joining The Aerospace Corporation, Dr. Adang completed a distinguished 27-year career in the US Marine Corps and US Air Force, including assignments with the NRO, Air Force Space Command, Strategic Air Command, and Air Combat Command; he also served as the Air Force deputy director of weather and as commander, Detachment 085, Air Force ROTC, University of California–Berkeley. Dr. Adang is a graduate of the Air War College.



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