8. Intelligence, Surveillance, and Reconnaissance

Area Description

Joint Vision 2020 depends on information superiority for virtually every aspect of military activity. The combination of intelligence, surveillance and reconnaissance (ISR), together with real-time communications and information processing technologies, is its enabler. It involves primarily electronic systems to find, watch and collect data from sources and provide it as information to users.

ISR permeates almost every area of national security activity, from peace through war. It involves techniques and systems operating both passively and actively in all operational environments from subsurface to space. A key benefit of this capability, from data collection through warning to its timely use by warfighters, is political and/or military success — through knowing more and knowing it sooner than opponents.

ISR includes information about: all operational threats to U.S. and Allied lives, assets, and interests; military force movements; all spacelift vehicles, missile systems (mobile or fixed), and spacecraft; all aircraft types, land-operating systems, and surface/submerged maritime vessels; nuclear detonations; threats to friendly space assets; chemical and/or biological weapons; and other significant space, surface and subsurface events. ISR activities support the intelligence and warning needs of all Services, the National Command Authorities (NCA) and other government agencies, support U.S. and Allied operations, and assist in international treaty monitoring.

The major goal of ISR is success through information dominance. Increasing demands for precise, finished intelligence on a wide range of defense intelligence requirements strain the resources currently available. Space-based intelligence collection capabilities have matured into powerful and reliable systems, able to meet a much larger fraction of the validated user requirements than ever before. Under today's exploitation and dissemination paradigms, our available personnel, communications and hardware cannot fully utilize the available data. Thus the Intelligence Community is pursuing a full range of technologies not only to enhance the collection of necessary data but also to examine new ways to produce and disseminate the information our users need. This approach includes:

- New and potentially revolutionary collection systems
- New analysis and dissemination methods and paradigms
- Significant improvements in data processing, storage-retrieval, and request-redistribution functions.

An evolving concept to deal with the multiplicity of evolving ISR and related information distribution concepts is contained in the term "infosphere." This construct involves information collection and integration across all activities (fusion), with follow-on processing to tailor its disseminated products for specific warfighters and other users.

Specific concerns and evolving needs include the following:

- The orbits of space-based ISR systems are currently predictable. However, if (per SatOps concepts) it becomes possible to maneuver them at will, an adversary would find it much more difficult to avoid detection or to interfere with them. Further, if they could be refueled on-orbit, they could be maneuvered to counter adversaries' operational planning or direct attack, without shortening mission life.
- Infrared detection of missile launches remains a key element of tactical warning; hence DoD's support for the Space-Based Infrared System (SBIRS) program as a replacement for the aging Defense Support Program (DSP) warning satellites.
- A space-based radar capability is needed to enable continuous (24-hour) full-global coverage. Benefits would include precision maps, detection and continuous tracking of sea, ground and air moving targets, and accurate real-time determination of orders of battle (OOBs).

- Proliferation of nuclear/biological/chemical (NBC) weapons requires counterproliferation technologies and capabilities as soon as practical.
- Transition from legacy systems to new ones, such as elevation of Airborne Warning and Control System (AWACS) and Joint Surveillance and Target Attack Radar System (JSTARS) capabilities to space and the increasing use of unmanned aerial vehicles (UAVs) and space sensor platforms, is needed to meet the ISR needs of warfighters everywhere.

Mission Area Objectives

- Global day/night all-weather surveillance and reconnaissance (as basis for situational awareness)
- Timely threat warning infomation (land, sea, air, and space)
  - Detect, track and ID ballistic and cruise missiles, and fixed or moving objects, signals or signatures, worldwide
  - Locate missile launch points, predict their impact points
- Real-time detection, ID, characterization and geolocation of fixed surface/subsurface and mobile targets:
  - Target set detection/surveillance/monitoring/tracking
  - Information on camouflaged, concealed and deceptive (CC&D), deeply buried and other "hard" targets
  - Ability to defeat attempts to schedule activities to avoid detection
- Information on NBC weapons and events
- Intelligence planning, tasking, cross-cueing, fusion, processing, and dissemination

Supporting Capabilities

Modular spacecraft designs for efficient integration, launch and on-orbit “plug and play”

Tactical agility with minimal involvement of ground support personnel

On-orbit propulsion to maneuver spacecraft at will

Higher data rate communications and information processing for fixed and mobile users

Flexible, multi-level information security

On-board processing

Automated cross-cueing

Efficient space-to-space crosslinks

Adaptive, autonomous sensors

Continuous surveillance/long-dwell coverage

Systemic counter-countermeasures

Elevation of AWACS and JSTARS capabilities to space

Surveillance platforms with ultra-lightweight deployable optics and antennas

Combined GMTI and SAR imaging from space

Constellations to provide global coverage

Space-based NBC materials detection

Advanced multi-, hyper- and ultra-spectral information content collection and exploitation

Enhanced target-to-background contrast ratios, target signature characterization, and modeling

Improved characterization of hardened and deeply buried targets

Current Technology Initiatives *(Highlights of Current FYDP)*

Near-term focus is on multi-mission technologies that have application to both air and space surveillance missions. Two such areas are hyperspectral imaging (HSI) and space-based radar (SBR) development.

The HSI program is developing day/night HSI technology capable of rapid precision threat identification and targeting of space, air and surface targets with a longer-term space goal of HSI systems on orbit as part of a national HSI architecture. Technologies include high-resolution focal planes, long-life cryocoolers, on-board signal processing, spectral exploitation algorithms, atmospheric compensation (both reflective and emissive), generation of spectral databases of targets and backgrounds, data fusion technologies, and high-performance computing and displays.

Per Congressional guidance on SBR development, both specific and generic technologies are being pursued:

- Specific projects applicable to airborne and ground moving target indication (AMTI/GMTI) SBR concepts include: affordable, lightweight active transmit/receive antenna modules, spacecraft power management and distribution, and high-efficiency microwave transmit and receive devices
- Generic technology areas extensible to SBR functions include ISR modeling and simulation, bistatic clutter characterization, space-time adaptive algorithm development, improved front-end noise rejection for RF systems, analog-to-digital converters, and advanced RF systems.

The NRO is continuing to develop low-cost Electronically Scanned Array (ESA) technology initiated under the former joint Discoverer II program. In addition, the NRO is examining opportunities and concepts of operations for radar-related experiments and demonstrations using currently available assets.

Additional projects and detail are tabulated in "Projected Applications," below.

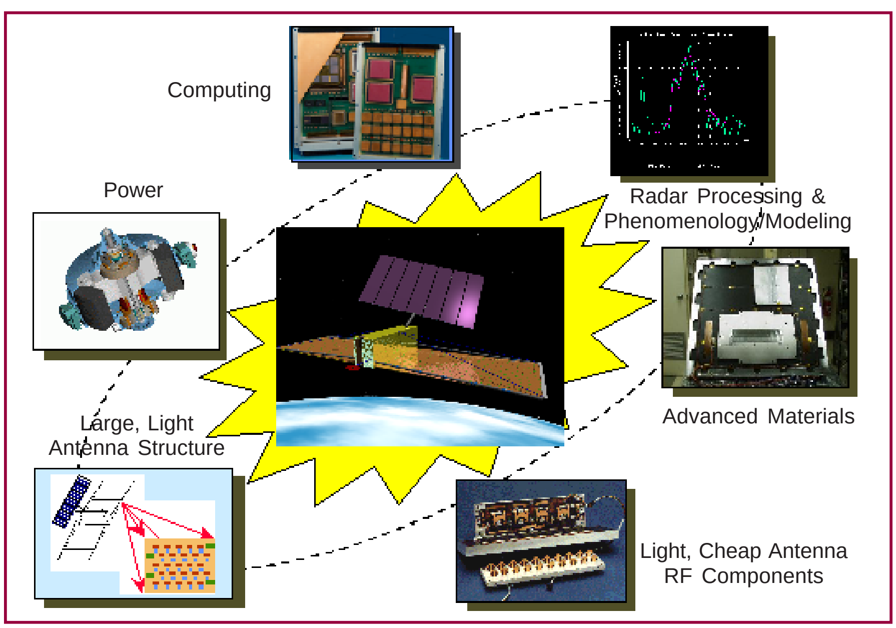
Enabling Technologies *(Unconstrained)*

- Autonomous, adaptive, self-training, error-correction and real-time planning algorithms for tasking, mission planning/management, target ID/tracking and battlefield learning, and data compression, processing, exploitation, and dissemination
- Automated cross-cueing, dynamic database fusion, geographic information systems (GIS), and synergy of imaging, spectral and signal functions, phenomena and information technologies
- Increased satellite on-board data processing and storage for timely data delivery
  - Non-volatile random access memory
- ISR modeling and simulation
- Miniaturized, scalable, power-efficient electronic components and mechanisms
  - E.g., fiber optics, optoelectronics, photonics, microelectromechanical systems (MEMS)
  - E.g., high-temperature superconducting electronics to eliminate need for sensor cryocooling
- Large, lightweight support structures and materials
- Shape memory techniques and alloy materials
- Active and passive electromagnetic spectrum devices to direct, disseminate, focus and transmit — as well as to detect, extract, sense and receive — energy:
  - Heat (infrared [IR])
  - Visible light
  - Radio frequency (RF)
- Fusion processing software algorithms
- Increased sensor range and sensitivity technologies
  - Atmospheric and radiant background characterization, modeling, and processing

- Improved atmospheric compensation and target classification algorithms for multi-spectral/hyperspectral image processing
- Exploitation technologies for bistatic phenomenology of targets and clutter characteristics
  - Bistatic space-time adaptive processing algorithm validation
  - True time-delay processing
- Multistatic time and frequency correlation, signal processing, and data fusion
- Advanced target detection technologies
  - E.g., acousto-optical detection and spectral signature exploitation (to see through clouds)
- Non-intrusive inspection technology
- Advanced electro-optical (EO) technology
- Hyperspectral sensing: improved low-power high-capacity on-board processors
- Hyper- to ultra-spectral imagery (HSI-USI) sensors (100s to 1000s of bands)
- Advanced IR technologies
  - Quantum cascade and interband semiconductor IR laser sources
- Multispectral/hyperspectral and very short wavelength infrared (VSWIR) sensors/imagers
  - Multi- to ultra-spectral detector materials, processes, and manufacturing
- Large focal plane array (FPA) detector materials science and manufacturing
  - E.g., staring FPAs for multispectral detection, read-out integrated circuits (ROICs), quantum well IR photodetectors (QWIPs)
- Advanced small, high-capacity, space-qualified cryocoolers
  - More efficient on-orbit storage of cryogenic hydrogen
  - More efficient infrared applications
  - Advanced regenerator/phase-change materials
- Low-power laser atmospheric compensation and beam control
  - Optical phase conjugation
  - Adaptive laser optics
  - On-orbit dimensional control
  - Jitter and vibration management
- Advanced acquisition, pointing and tracking techniques
- Space-based high-resolution optical/radar/multi-spectral imaging technologies (active or passive)
- Space-based laser, lidar or relay mirrors for remote optical sensing
  - Large-aperture, lightweight, modular, deployable membrane mirrors/optics, and support structure materials
- Durable thin-film substrate/membrane/coating materials, processing, and manufacturing
- Nonlinear optical materials for specialized sensors and biological/chemical threat detection
- Optically efficient and variable-emittance mirror coatings
- On-orbit servicing of mirror coatings
- Advanced RF technology
  - Photonics for phase-shifting and beam-forming
  - Spectral analyzers and algorithms
  - Digital RF memory (DRFM)
- Advanced synthetic aperture radar (SAR)
  - E.g., inverse and interferometric SAR
- Advanced automatic target recognition (ATR), moving target indication (MTI), and orbital dynamics processing algorithms
- Large affordable, lightweight RF reflectors and antenna designs
  - E.g. inflatables, deployable array-fed reflectors
  - E.g. solid state phased array electronically steerable antennas
  - Higher strength-to-weight and composite materials and designs
- Radar components with higher frequency and power output
  - High-temperature semiconductor materials for RF/radar components

- W-band low noise vacuum electronics
- X-band solid state (wide bandgap) components

- Technologies for receivers, waveforms and antennas to enable:
  - Penetration of clouds, obscurants, foliage, and terrestrial structures
  - Control/adjustment of signals, power, and frequencies to enable better signal penetration and jam-resistance
- Advanced, lower-cost, higher-frequency/bandwidth transmit/receive (T/R) components
- Improved front-end noise rejection for RF systems
- Advanced mixers and analog-to-digital (A/D) converters
- Advanced signal excision techniques
- Laser/optical communications and associated acquisition/tracking/pointing for space-space, space-air, and space-ground applications
- Non-volatile memory optical computing/communications
- Advanced laser and microwave communications technologies for space-space, space-air, space-ground links
  - Advanced netting and encryption technologies
- Reprogrammable radios and other electronics system components
  - Field programmable gate array (FPGA) technologies
- More efficient solar cells, batteries (chemically or thermally generated electricity, such as thermionic power generation and thermo-electric conversion)
  - E.g., lithium ion/polymer hybrid batteries
  - Affordable solar cell materials and manufacturing
- Radiation hardening and shielding of components
  - Radiation-resistant composites and associated materials
  - High-temperature and radiation-resistant electronic materials
  - Flash radiation-hardened digital memory (e.g., SiC)
- Satellite laser and RF interference/vulnerability mitigation
  - Bi-/multistatic techniques
  - Synthetic/virtual apertures
- Isothermality technologies
- High heat-dissipating thermal doubler/plane materials
- Advanced effects phenomenology
- Human-system interfaces for information exploitation and decision-making
- Control center technologies
  - Write once read many (WORM) storage
  - Archival mass storage.



Space-Based Radar (SBR) Concept

Projected Applications

These unclassified technology and program listings represent a major portion of ISR technology investment. Other initiatives, programs and collaborations are classified.

Category	Project / Activity	Status	Agencies
Advanced Target Detection and Imaging	• ***Infrared (IR) technologies*** for target detection, e.g.:		Air Force
	– Space-Based Infrared System (SBIRS) -High	EMD	
	– SBIRS-Low	Dem/Val	
	• ***Space-Based Radar (SBR) technologies***	Technology developments	Air Force (lead) DARPA, NRO, Army
	– Airborne moving target indication (AMTI)		
	– Ground moving target indication (GMTI)		
	– SBR with GMTI and SAR imaging (space-based sensor support to operations)		
	• ***Hyperspectral Imaging (HSI) projects*** to address HSI utility issues:	Technology demonstrations	
	– Warfighter I		Air Force
	– EO-1		NASA
	– Multispectral Thermal Imager (MTI)		DOE
	• ***Space-Based Laser (SBL) Imaging***	Concepts, experiments, developments	Air Force
	– Lighter, cheaper, stable, large space optics		
	– On-orbit resupply concepts		
	• ***Space Maneuver Vehicle (SMV)***	System concept	Air Force
	– Tailored ISR constellations		
	– Interchangeable ISR payloads		
Platform Technologies	• ***Generic spacecraft projects***	Concepts, experiments, developments	(Several)
	– Radiation-hardening technology programs		
	– Processor development activities		
	– Battery development activities		
	– (See **SatOps** concepts and projects		
	– *(Other classified activities)*		
Information Management	• ***Real-time global awareness***	Concepts, experiments, developments	Government interagency activities (DoD, NASA, others)
	– Consistent battlespace picture		
	— To provide a common operational context		
	– Automatic target recognition (ATR)		
	– Broadband crosslinks and downlinks		
	— To support data processing		
	– Tactical display feeds		
	— To disseminate ISR products and services		
	– Future information, fusion and dissemination architectures		
	– Information exploitation technologies		

DemVal Demonstration/Validation acquisition phase EMD Engineering and Manufacturing Development phase

Opportunities for Partnering

The DoD, DOE and NASA Space Technology Alliance (STA) coordinates development of affordable technologies with applications to space.

The National Security Space Architect (NSSA) is developing, coordinating and integrating DoD and IC space architectures. Meanwhile DoD, civil and commercial systems need to be integrated to achieve required capabilities at affordable cost, to include:

- Integration of NRO sensor and communications systems in theater operations
- Cooperation with other agencies, such as NOAA for weather satellites
- Coordination among Service space activities
- Finding best ways to use commercial space capabilities.

Air Force work to make large space optics lighter, stable and cheaper may also benefit NASA and other space systems and concepts.

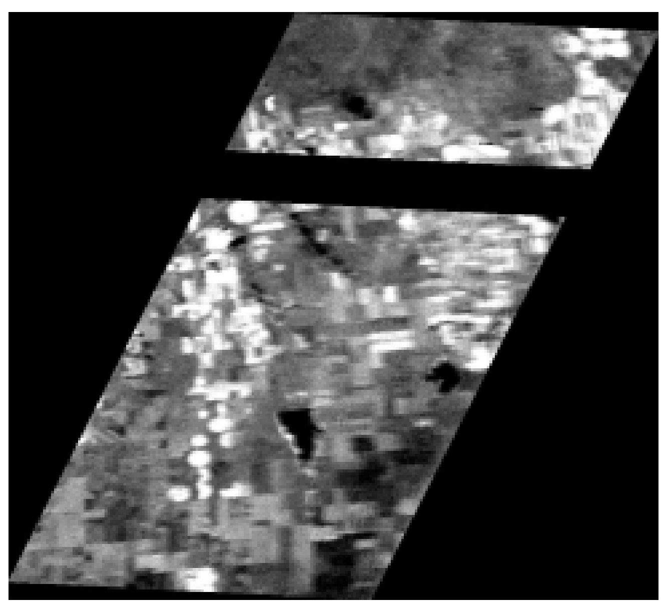
The DoD and IC are beginning to share the burdens of basic technology development and costs of the industrial infrastructure with commercial industry (e.g., the NRO is already using a commercial bus for some satellite systems). Lessons learned from mass manufacturing of commercial satellites will benefit both government and industry.

In the area of commercial remote sensing, NIMA acquires commercial imagery from multiple vendors both for geospatial data production and for peacetime and crisis applications. NIMA will also acquire unclassified imagery from new high-resolution commercial remote sensing systems with enhanced spectral capabilities. A joint government-industry team will identify the best data acquisition approach for the future.

Meanwhile, broadband demands of an SBR system and similar anticipated commercial systems may result in a very difficult frequency allocation challenge. Here, the DoD should use commercial industry's influence in the international arena to achieve common solutions.

MightySat II.1 Fourier Transform Hypersepectral Imager (FTHSI):
First Image From Space (Georectified)

False Color IR Image (3 bands)



Grayscale Image (λ =775)