Perspectives on Worldwide Spaceborne Radar Programs

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Abstract — **Radar technology and techniques were originally developed for land-based, maritime, and airborne applications. Spaceborne radar systems development began in the 1960s in the USSR for military purposes, and in the 1970s in the United States for civilian scientific purposes. NASA launched the SeaSAT satellite in 1978, carrying a synthetic aperture radar, a radar altimeter, a radar scatterometer, and a radiometer, ushering in the modern era of spaceborne radar observations. NASA embarked on a shuttle-based space radar program in the 1980s that was geared to advancing space radar technology and demonstrating scientific utility of multi-parameter synthetic aperture radar, culminating in the Shuttle Imaging Radar-C flights in 1994. With the launch of the European Space Agency ERS satellite and the Japanese JERS satellite in 1992, and the Canadian Radarsat satellite in 1995, international systems have had a persistent orbiting radar presence in space around the Earth, replenished with new systems with increasing emphasis on dual use capabilities, while the US has fielded only one Earth orbiting space radar system for a 10-day period in 2000, the Shuttle Radar Topography Mission. The US program has evolved differently, with emphasis on mapping SARs for the planet Venus and Saturn's moon Titan, and a series of targeted scientific platforms focusing on Earth system and climate studies: TOPEX altimetry and follow-ons for ocean topography, QuikScat scatterometer for global winds, and TRMM and Cloudsat for precipitation and cloud water content. Radar programs worldwide are flourishing as the technology advances and new scientific uses and applications are generated from the abundant globally acquired data from international systems. Questions of security and global competition are now complicating the development of highly capable systems, such as the SAR systems required for persistent surveillance in both the military and scientific arenas.**

Index Terms—**radar, synthetic aperture radar, international SAR, altimeters, scatterometers**

I. Introduction/History of Spaceborne Radar Developments

Space faring nations are increasingly embracing remote sensing radar systems for Earth and planetary science, as well as military and commercial applications. Radar has proven to be an important contributor to broad areas of science, including ocean science, atmospheric science, land-cover classification, geophysics, and geodesy. To probe the enormous range of processes and spatial and temporal scales, a variety of instrument types have been developed, the characteristics of each being tailored to a particular observation of interest. Radar instruments that have flown in space include real-aperture radars such as sounders, altimeters, and scatterometers, and synthetic aperture imaging radars. Kramer[1] gives an extensive overview of radar missions and sensors, with updates available electronically[2]. This paper further updates the missions, and uses these data to interpret trends in spaceborne radar programs and prospects for the future. This paper covers the major missions and programs past, present, and with high probability for the future, i.e., those that have had or are likely to have an impact on our understanding of the world, or that established an observational trend for its epoch.

The modern era of space radar surveillance was ushered in with the SeaSAT-A mission, which carried an altimeter, radiometer, scatterometer, and SAR system. Though SeaSAT operated for only 90 days on orbit before a spacecraft failure, its legacy is evident as a testbed for a series of future radar satellites orbiting earth and other planets. In particular, missions that grew from the SeaSAT Ku-band altimeter include GEOSAT and GEOSAT Follow-on, TOPEX/POSEIDON (1992-2005), JASON-1 (2001-), and the Ocean Surface Topography Mission (2007). The Ku-band scatterometer on SeaSAT was the model for the NSCAT scatterometer on ADEOS (1996), which led to the SeaWinds instrument on QuikScat (1999-) and on ADEOS 2 (2002).

The L-band SAR on SeaSAT led directly to the Shuttle-Imaging Radar A (SIR-A) and SIR-B L-band missions; spare SeaSAT equipment was flown on SIR-A (1981) and SIR-B (1984). The experience gained from the SIR-A/B experiments led to the development of an entirely new and powerful sensor, SIR-C/X-SAR, comprised of an L- and C-band, fully-polarimetric SAR system contributed by the US and a single-polarization X-band system contributed by Germany and Italy. Two 10-day flights of SIR-C took place in 1994.

The success of SIR-C/X-SAR then led to an augmentation of the instrument to include a 60-meter deployable boom and a second receive-only C-band and X-band antenna placed at the end of the boom, known as the Shuttle Radar Topography Mission, a US/German/Italian collaboration funded jointly by NASA and the National Geospatial Intelligence Agency (then NIMA). Enhanced with a metrology package that could determine the location of the extended antenna relative to the shuttle, SRTM was a two-aperture interferometer, operating in ScanSAR mode at C-band to increase coverage so that the entire land surface between +/- 60 degrees latitude could be mapped twice in the 10-day mission.

SeaSAT also influenced the development of Magellan, the first successful planetary radar mapping mission. Magellan carried an S-band radar to map the surface of Venus (1989-1994).

In the international arena, the Japanese satellite JERS-1 (1992-1998) carried an L-band single polarization SAR similar to SeaSAT in its instrument and orbit characteristics. The European ERS-1(1992-2000) and ERS-2 (1995-) satellites followed the SeaSAT model in having an altimeter, scatterometer, and SAR instrument on each spacecraft.

II. CURRENT RADAR MISSIONS

In addition to those currently operating radar missions listed in the previous section, there are a number of other systems in orbit. Table 1 summarizes the full suite of operating radar missions. Here we give brief accounts of their salient characteristics, both technical and programmatic.

QuikScat[3] As a rapid follow-on to the NSCAT system on the short-lived Japanese ADEOS spacecraft, NASA flew the Seawinds prototype Ku-band scatterometer instrument in 1999. The system has two off-nadir beams on an antenna fixture rotating 16 times per minute, giving four vector measurements of surface winds as the spacecraft orbits. The system is still in operation.

TRMM[4] The Tropical Rain Monitoring Mission carries a precipitation radar jointly developed by NASDA and CRL in Japan. The radar operates at 13.8 GHz, recording energy reflected from atmospheric and surface targets. The radar electronically scans from right to left, looking in the +X direction across the ground track of the satellite every 0.6 seconds with a swath width of 215 km.

JASON-1[5] is an altimetry mission, jointly developed by the US and France as a follow-on to TOPEX/Poseidon. The CNES Poseidon-2 altimeter is the mission's main instrument, derived from the experimental Poseidon-1 altimeter on TOPEX/ Poseidon, a dual frequency (C-/Ku-band) instrument. Two frequencies are used to correct for ionospheric contribution to the delay.

Cloudsat[6] The Cloud Profiling Radar (CPR) on Cloudsat is a 94-GHz nadir-looking radar. The sensitivity of CPR is defined by a minimum detectable reflectivity factor of -26 dBZ, along-track sampling of 2 km, a dynamic range of 70 dB, 500 m vertical resolution and calibration accuracy of 1.5 dB. Launched in spring 2006, Cloudsat orbits in close formation with several other atmospheric sensing satellites, including Aura, Aqua, Calipso, Parasol, and eventually OCO.

ERS-2[7] ESA's European Remote Sensing Satellite-2 (ERS-2), launched in April 1995, is the companion mission to ESA's now defunct ERS-1. ERS-2 features an active microwave instrument (AMI), as well as a radar altimeter (RA-1). AMI can operate in a SAR imaging mode, a wave mode, or as a wind scatterometer (AMI-SCAT). The primary mission of ERS-2 has been environmental monitoring. Operational programs are in place for sea ice mapping, oil slick monitoring, and ship detection. From October 1995 to June 1996, ERS-2 operated in tandem with ERS-1 as a 1-day repeat InSAR, obtaining a large dataset of topographic and change detection measurements. ERS-2 remains operational well beyond its three-year design life.

Table 1. Current Radar Missions in Operation

System/ Instrument	Country	Owner/Operator	Prime	Launch Date(s)	Orbit Altitude (km)	Repeat Cycle (days)
QuikScat/ Seawinds	USA	NASA	JPL	Jun-99	803	
TRMM	USA, Japan	NASA, JAXA	GSFC	Nov-97	402.5	
Cassini	USA, Italy	NASA	JPL	Oct-97	(Saturn/ Titan)	
Cloudsat	USA	NASA	JPL	Apr-06	705	
JASON-1/ Poseidon-2	USA, France	NASA, CNES	Alcatel	Dec-01	1336	10
MRO/ SHARAD	USA, Italy	NASA	JPL	Aug-05	(Mars)	
Radarsat-1	Canada	CSA	Spar Aerospace	Nov-95	798	24
Mars Express/ MARSIS	ESA, USA, Italy	ESA/ASI/NASA	Alenia/JPL	Jun-03	(Mars)	
ERS-2	ESA	ESA	EADS Astrium	Apr-95	800	35
ENVISAT	ESA	ESA	EADS Astrium	Mar-02	800	35
SAR Lupe	Germany	BMVg	OHB System	Dec-07	500	NR
ALOS/ PALSAR	Japan	JAXA	NEC, Toshiba, MELCO	Jan-06	692	46
IGS	Japan	MOD	MELCO	Mar-07	NR	NR

Radarsat-1[8] Canada ushered in a new paradigm in remote sensing with the launch of its Radarsat-1 in November 1995. The primary mission of the C-band Radarsat-1 is environmental monitoring, in particular ice monitoring. Radarsat-1, funded by the Canadian Space Agency (CSA), has civil, commercial, and military/intelligence customers. The satellite has greatly exceeded its five year design lifetime. NASA is a partner in the Radarsat-1 program and provided the launch onboard a Delta II.

ENVISAT[9] ESA's Environmental Satellite (Envisat) was launched in March 2002. ENVISAT is part of a continuum of ESA satellites (including ERS) with the missions of environmental monitoring and disaster mitigation. Envisat's mission is concerned, in particular, with monitoring the oceans and ice. ENVISAT has a large payload complement, including the C-band Advanced SAR (ASAR) and a radar altimeter (RA-2). ENVISAT remains operational and funded as it nears the end of its 5-year nominal lifetime.

IGS[10,11] Japan's Information Gathering Satellite (IGS) program initiated development in 1998. A pair of satellites was launched in March 2003, one carrying a high-resolution electro-optical sensor, and the other a SAR. The launch of a second pair in November 2003 was unsuccessful due to launch vehicle failure. Launch of a SAR satellite only is expected in February 2007. Most details of the program, as well as the data, are classified. Japan has announced its intention to pursue follow-on IGS programs.

ALOS[12,13] The Advanced Land Observing Satellite, is Japan's most ambitious Earth observing program to date.

Sponsored by the Japanese Aerospace Exploration Agency (JAXA), the civil-commercial ALOS has missions in mapping, environmental monitoring, and disaster mitigation. ALOS features three instruments, including the Phased Array L-Band Synthetic Aperture Radar (PALSAR). ALOS was launched via Japan's H-IIA launch vehicle in January 2006. Data are now available for distribution via civil and commercial channels. The planned lifetime of ALOS is five years.

Cassini Radar[14] is a Ku-band system orbiting Saturn, designed to make detailed measurements of the cloud-covered moon, Titan. Cassini radar has a multi-feed antenna system that creates five fixed radar beams to maximize cross-track coverage during a fly-by of Titan. The radar can operate in altimeter and scatterometer modes using the main beam, as well as SAR mode on all beams. Between radar pulses, the system functions as a radiometer as well. Cassini began its observations of Titan in 2004 and continues to generate new data with each pass-by allocated to radar observations.

MARSIS[15] is a planetary sounder, jointly developed by the US and Italy, orbiting Mars on the European Mars Express satellite. It operates in the frequency range of 1 MHz to 5 MHz in separate bands, and is used for ionospheric sounding when the ionosphere is active, and for subsurface sounding when the ionosphere does not block propagation, down to 2 km depth.

SHARAD[16] is a planetary sounder developed by the US and Italy, operating in the 20 MHz range. It was designed to penetrate in the top 100 m of the subsurface of Mars, to characterize the structure just below the surface. SHARAD is orbiting Mars on the US Mars Reconnaissance Orbiter.

SAR Lupe,[17,18,19] Germany's first spaceborne reconnaissance system, is an ambitious program to pursue well-established SAR and spacecraft technology to provide a large quantity of SAR data for a very low cost. The owner and operator of the system, Germany's Ministry of Defense (BMVg), selected OHB System as the prime contractor for SAR Lupe. The system will consist of five identical spacecraft with the primary mission of high resolution SAR. The first SAR Lupe was launched onboard a COSMOS 3M in December of 2006 and was recently declared operational. Subsequent launches are expected every six months thereafter until the constellation is fully populated. All data from the system will be classified by the German government and will not be publicly released.

III. Radar Missions Under Development

Neither the US Government nor US industry has mature plans to deploy an operational civil spaceborne SAR system. That situation is in marked contrast to foreign nations, where a number of capable SAR systems are in advanced stages of development. This section describes the development and capabilities of these near-term spaceborne SAR programs. All systems are described based on publicly released information. Table 2 summarizes radar missions under development.

Chandrayan/LRO SAR[20] The Indian lunar mission Chandrayan will carry a small S-band SAR science payload to map portions of the moon. This payload is currently under development by an extended family of US agencies and contractors, led by Paul Spudis as instrument principal investigator. A follow-on instrument with added capability is being developed by related partners to fly on the US Lunar Reconnaissance Orbiter.

Radarsat-2[21,22,23,24] is the follow-on satellite to Canada's highly successful Radarsat-1. Radarsat-2 is a multiple-user

Table 2. Radar Missions in Development

System/ Instrument	Country	Owner/Operator	Prime	Launch Date(s)	Status	Orbit Altitude (km)	Repeat Cycle (days)
JASON-2/ Poseidon-3	USA, France	NASA, CNES	Alcatel	Jun-08	In build.	1336	10
Aquarius	USA, Argentina	NASA/CONAE	JPL/GSFC	Jul-09	In build.	657	
LRO-SAR	USA	NASA	GSFC/APL	NET2009	In build.	100 (Moon)	
SAOCOM	Argentina	CONAE	INVAP	NET 2008	In build.	NR	16
Radarsat-2	Canada	CSA	MDA	Mar-07	Awaiting launch.	798	24
HJ-1C	China	National Committee for Disaster Reduction	IECAS	2007	In build.	500	31
TerraSAR-X	Germany	DLR	EADS Astrium	Feb-07	Awaiting launch.	514	11
TanDEM-X	Germany	DLR	EADS Astrium	NET 2008	In build.	514	11
Sentinel-1	ESA	ESA	TBD	2011	In development.	TBD	12
Chandrayan	India, USA	ISRO/NASA	ISRO/APL	NET 2008	In build.	100 (Moon)	
RISAT	India	ISRO	ISRO	2008	In build.	690	13
TECSAR	Israel	MOD (Israel)	IAI/ELTA	2007	Awaiting launch.	NR	NR
COSMO/ SkyMed	Italy	ASI/MOD (Italy)	Alcatel Alenia Spazio	2007	In build.	620	16
Kompsat-5	South Korea	KARI	KARI/EADS Astrium	NET 2008	In build.	NR	NR

system with commercial, civil, and military-intelligence customers. Although commissioned by CSA, the prime contractor, MDA, will own and operate the system. Radarsat-2 was developed under a civil-commercial partnership funded primarily by the Canadian government, with secondary funding provided by MDA. There is significant involvement of the European space industry as sub-contractors to MDA and the payload contractor, EMS Technologies (Canada). Radarsat-2 is currently awaiting a March 2007 Soyuz II launch. The planned mission life is seven years. The distribution terms for Radarsat-2 data are governed by Canadian law and a license agreement between the buyer and MDA.

HJ-1C[25,26] The Small Satellite Constellation for Environment Protection and Disaster Monitoring, referred to as the HJ constellation, is a project proposed by the Chinese National Committee for Disaster Reduction and State Environmental Protection Administration. The objective of the HJ constellation is to establish an operational system for disaster monitoring and mitigation. The full constellation is envisioned as a network of eight small satellites. Three satellites, two electro-optical and one SAR, are funded. Five additional satellites, two electro-optical and three SAR, are proposed for launch by 2010 to complete the HJ constellation. The S-band HJ-1C will feature a netted parabolic antenna. HJ-1C is tentatively scheduled for launch in 2007. Data availability has not yet been determined.

TerraSAR-X[27] is civil-commercial system funded by EADS Astrium and the German Aerospace Center (DLR) with the primary mission of collecting high-resolution imagery for civil and commercial use. In addition to conventional imagery, DLR plans to conduct experiments in repeat-pass differential InSAR. The radar also has a dual receive antenna mode for along track interferometry (ATI) that allows full quad polarization and may be used for ocean traffic monitoring, ocean current monitoring, and moving target indication (MTI). TerraSAR-X will be launched in February 2007 via a DNEPR. The planned mission life is five years. DLR will be the owner of the TerraSAR-X satellite as well as the responsible party for scientific utilization of the data. Infoterra, a subsidiary of Astrium, will have exclusive commercial data exploitation rights. Data distribution will be subject to a data security policy to be enacted by the German government, the details of which have not been released.

TanDEM-X[28] Procurement of the TanDEM-X spacecraft was announced in May 2006. TanDEM-X will use an additional spacecraft, essentially a clone of TerraSAR-X, flying in formation with TerraSAR-X in order to perform single pass InSAR. The objective of TanDEM-X is to produce a global digital terrain elevation data (DTED) dataset of level 3 or better within three years. TanDEM-X is currently planned to launch in the 2008 timeframe.

RISAT-1[29] The Indian Space Research Organization (ISRO) is developing the RISAT mission. RISAT is a multi-user system with missions in land resource studies, oceanographic studies, and "high resolution studies" (e.g., change detection). RISAT will augment India's already robust operational remote sensing program by enhancing agricultural and disaster related applications. A 2008 launch aboard India's PSLV is expected. The mission lifetime is five years. Data will be distributed by the Antrix Corporation.

TECSAR[30,31] is the first radar component of an Israeli effort to field a system of intelligence satellites. It is described as a technology demonstration SAR satellite with the goal of developing the technology required for high resolution SAR imagery combined with large area coverage. TECSAR is being developed by ELTA Systems, a subsidiary of Israeli Aircraft Industries (IAI). The TECSAR radar is an X-band system utilizing a parabolic reflector antenna. Launch is planned for early 2007 onboard a PSLV. Data will not be publicly distributed.

COSMO/SkyMed[32,33] is a dual use civil-military/intelligence SAR system being built by Alcatel Alenia Spazio for the Italian Space Agency (ASI) and the Italian Ministry of Defense. COSMO/SkyMed is a constellation of four identical satellites to be launched consecutively. The X-band active array antenna is composed of five horizontal panels. The phased array uses a single T/R module for each element, therefore only one polarization can be collected at a time. A fully polarimetric scheme can be implemented by splitting the antenna into two sub-apertures that each receive different polarizations. Proposals have been presented describing the potential of splitting the antenna of the COSMO/SkyMed Radar into multiple sub-apertures (up to five). This technique may allow detection of ground moving targets (MTI), ocean current and wave monitoring using along track interferometry (ATI), and fully polarimetric imaging. No firm launch date for COSMO/SkyMed has been given. A five-year lifetime is planned. The data distribution policy for COSMO/SkyMed has not been released, however, some public data distribution is likely. As referred to above, COSMO/SkyMed is also part of a cooperative effort (SIASGE) with Argentina's SAOCOM.

Kompsat-5[34] will be South Korea's first spaceborne SAR. Best resolution is proposed to be between 1 m and 3 m. Development with EADS Astrium began in 2005. Launch is planned for 2008.

JASON-2,[35] also known as the Ocean Surface Topography Mission, is a follow-on to JASON-1, carrying the next generation CNES Poseidon-3 altimeter. It is scheduled to launch in 2008.

Cryosat[36] is a Ku-band altimeter mission of Poseidon heritage being built by ESA to measure polar ice. It has a number of modes that render it particularly well suited to measuring land ice, including a SAR altimeter mode for improved (250 m versus typical 5 km) resolution along track, and a two-aperture interferometric mode for measuring topography across track. The first Cryosat failed on launch in 2005. ESA quickly decided to fund a recovery mission.

Sentinel-1[37,38] is a constellation of satellites proposed as part of the European-led global monitoring for environment and security (GMES) concept. Germany plans to be the largest contributor to the GMES space component, beginning with the Sentinel-1 C-band SAR. The current baseline calls for a dual polarization SAR system utilizing an active array antenna. Launch is planned for mid-2011. A key schedule constraint is to avoid any gap in European C-band radar capability with the end-of-life of ERS-2 and ENVISAT in the same timeframe.

SAOCOM[39,40,41] will be Argentina's first satellite to carry a SAR as a payload. Two identical satellites, SAOCOM 1A and 1B, to be launched consecutively, are planned. The primary missions of SAOCOM are disaster management (e.g., flooding), economic activities (e.g., agriculture), and environmental monitoring (e.g., continental glaciers). These missions drove the selection of L-band for SAOCOM. SAOCOM is sponsored by Argentina's National Commission on Space Activities (CONAE). In the long term, the SAOCOM system is planned to be part of a joint Italy-Argentina radar constellation with the X-band COSMO/SkyMed system known as SIASGE (Sistema Italo-Argentino de Satélites para Gestión de Emergencias). It appears that economic problems in Argentina have impacted the development of SAOCOM, however, it is reported that the engineering models of the SAR electronics and active antenna have been developed. SAOCOM currently has no definitive launch date; any date earlier than 2008 is unlikely. A data distribution policy for SAOCOM has not been released.

IV. Analysis and Conclusions

It is clear from the trends described in this paper that space faring nations large and small are discovering the benefits of radar remote sensing instruments for characterizing the Earth and planets. The sequence of missions in the US began with SeaSAT in 1978 and peaked with the development of large and relatively costly systems in the mid-1990s, such as SIR-C and Cassini. Since then, radar missions have been down-sized to systems that are more affordable and targeted to specific science objectives, like Cloudsat. Similarly in Japan and Europe, the sequence of missions began in 1992, and shortly thereafter in Canada, with systems of similar capability to SeaSAT (though fortunately much longer-lived). These countries' programs are peaking now with their large multi-functional systems, and are looking to the future for lower cost radar systems more targeted to specific needs or dual-use capabilities. The newer entrants into the spaceborne radar community are going directly to low-cost targeted systems, for reasons of affordability more so than technology.

Future of Radar in the United States

The US does not have a civil spaceborne SAR mission currently, though over a decade has passed with the science and applications communities eager to have access to data such a program could provide. Numerous studies have called for SAR or interferometric SAR systems, most recently the NRC Decadal Survey for Earth Science[42]. NASA has continued to invest in SAR technology and airborne SAR testbeds, most recently the UAVSAR system, designed to perform repeat-pass interferometric observations of rapidly deforming areas[43]. And in the defense sector, the Space Radar Program[44] continues technology risk reduction at substantial funding levels. In this sense, the US is still committed to a future SAR capability, but has to this point not funded a free-flying SAR space mission.

NASA has embarked on a number of studies of dual-use (science/commercial, science/military, commercial/military) SAR missions, beginning with LightSAR in 1996[45]. These studies have led to the conclusion that such systems are not cost-effective: the requirements for each component are sufficiently disjoint that, in effect, the system must comprise two separate instrument suites and two separate mission profiles, raising cost and creating irreconcilable conflicts in the mission timeline. Radarsat has been able to contribute to many communities simultaneously, and has created a demand for similar radar data. The cost of the space segment was assumed by the Canadian Space Agency for Radarsat. The key to future success is for government and the private sector to create a market that would pay for commercial data at the full cost, including the space segment.

TerraSAR-X and other systems are attempting to create the market by reducing the cost of the flight segment, and gradually increasing investment by the private sector, with the goal that ultimately the entire system will be commercially procured. In this sense, the mission is not driven by science or measurement requirements. It is cost-driven, with the intent of creating a market that can use the data generated by the realized system. US missions have nearly always pushed the envelope in terms of improving upon science or technology – always more accuracy, more coverage, finer resolution, lower mass, more advanced electronics – which inevitably increases cost. For the US to succeed in dual-use ventures, an approach based on low cost may be necessary.

The US Earth and planetary science programs call for radar instruments in numerous disciplines. The NRC Decadal Survey for Earth Science calls for a suite of radars phased over the next decade. NASA is currently formulating plans for planetary missions, but the successes of Cassini at Titan, and the Mars sounders will likely point to missions with similar capabilities in the future. The ability to implement these missions will depend primarily on funding priorities for that portion of the NASA budget not devoted to the NASA Exploration Initiative.

Future of Radar in the World

Section III detailed rest-of-world (ROW) radar systems that are in the advanced planning stages or in development. In addition to those systems, there are numerous programs that are in preliminary stages of development or discussion. Those systems include: a follow-on to Radarsat-2 (Canada); a follow-on to TerraSAR-X (Germany); a follow-on to IGS

(Japan); Ricesat: an agricultural monitoring system (Asia); a military SAR (Spain)[46]; MicroSAR: a SmallSat SAR constellation (United Kingdom)[47]; and MAPSAR: a land monitoring SAR (Brazil/Germany)[48].

Whether or not the above systems come to fruition will largely be a function of the success or failure of the systems described in Section III. Such systems will be closely watched to see if a larger market for commercial SAR data develops. Providing new sources of data will not necessarily result in a viable market for SAR data and products. If such a market does develop, future system owners and operators will be most interested in what data and products the customer will pay for. While there has been a trend towards high resolution (i.e., 1 m to 3 m class systems), it is not clear that resolution is the primary metric for evaluating system usefulness to the customer. Metrics such as band, coverage, timeliness, and special products (e.g., polarimetry and interferometry) must also be considered.

ACKNOWLEDGEMENT

This paper was written at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration, and at The Aerospace Corporation. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government, the Jet Propulsion Laboratory, California Institute of Technology, or The Aerospace Corporation. All trademarks, service marks, and trade names are the property of their respective owners.

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