Division 4

REMOTE SENSING OF THE SURFACE AND WATER AREA OF EARTH («Surface» Project)

Lyalko V. I.

Centre for Aerospace Research of the Earth, Institute of Geological Sciences, NAS of Ukraine
55b, O. Gonchar St., Kyiv-54 01601Ukraine
tel/fax: (380) +44 +216 94 05, e-mail: casre@casre.kiev.ua

«Surface» Experiment

REMOTE SENSING OF THE SURFACE AND WATER AREAS OF EARTH BY THE UKRAINIAN ON-BOARD RADAR COMPLEX AND THE DATA FROM MULTI-SPECTRAL SURVEYS AND TESTING AREAS IN THE TERRITORY OF UKRAINE

Lyalko V. I., Fedorovsky A. D.

Centre for Aerospace Research of the Earth, Institute of Geological Sciences, NAS of Ukraine
55b, O. Gonchar St., Kyiv-54 01601, Ukraine
tel/fax: (380) +44 +216 94 05, e-mail: casre@casre.kiev.ua

Dovgij S. A.

Environment and Resources Research Institute of Ukraine,
National Security and Defense Council of Ukraine
Tel: (380) +44 +241 77 24

Bakan G. M.

Space Research Institute, NAS of Ukraine — NSA of Ukraine
40, Akademik Glushkov Ave., Kyiv 03022 Ukraine
tel/fax: (380) +44 +266 41 24, e-mail: iki@spase.is.kiev.ua

Korotaev G. K.

Marine Hydrophysical Institute, NAS of Ukraine
2 Kapitans'ka St., Sevastopol 99000 Ukraine
tel: (380) +692 +54 72 79, fax: (380) +692 +55 42 53,
e-mail: omnet-mhi.sevastopolrelcom-ocean@mhi2.sebastopol.us

Tcymbal V. N.

A. I. Kalmykov Centre for Radio Physical Sensing of Earth, NAS of Ukraine — NSA of Ukraine
12 Akademik Proskura St., Kharkiv 61085 Ukraine
tel/fax: (380) +572 +44 83 97, fax: (380) +572 +44 10 12, e-mail: kalmykov@ire.kharkov.ua

The Earth Remote Sensing (ERS) allows studying a lot of important problems, i. e. the global energy-mass transfer and weather forecasts, the local ecological control and mineral resources surveillance.

Development and introduction of effective ERS methods is especially important for Ukraine because of the strained ecological and economic situation. Large-scale international cooperation in the form of

collaboration for creation of the ISS, could be of great benefit for Ukraine in this field of research.

Installation of the ERS complex on-board the orbital station has advantages over single satellites accomplishing the ERS in the self-contained mode. The principal advantages are as follows:

— Control over experimental conditions; active analysis of the visual and concurrent information to determine the time of turning on the measuring instruments; possibility to correct the observational conditions.

— Integrated nature of the experiments; possibility of using dissimilar and diverse measuring instruments simultaneously.

— Active control over the satellite and ground-based blocks of the experiment during the sub-satellite measurements.

«Surface» project deals with a series of experiments to study the natural environment of Earth in optical, infrared, millimeter, centimeter, decimeter, and a meter ranges of waves and to improve the existing ERS methods of measurement. It is supposed that this project will enable meeting the following objectives:

— Ensuring a sufficiently active reaction of the astronaut to extraordinary processes and phenomena on the Earth's surface (earthquakes, floods, fires, landslides) by their surveying in various ranges of the electromagnetic radiation and preliminary physical interpretation of the data obtained.

— Repair and upgrading of on-board surveying apparatus.

— Optimization of the on-board surveying apparatus set without duplication of the appropriate apparatus of other satellites, as well as taking into account the limitations on power supply, overall dimensions, and electromagnetic compatibility with other on-board devices.

— Ensuring that the ISS surveying and surveying from other satellites (LANDSAT, SPOT, ERS, JERS, Radarsat, IRS, Resurs, Ocean-O, etc.) complement each other in terms of their orbits, seasons, phenophases of vegetation development, etc.

— Substantiation of the requirements to the testing grounds for ground-based calibration and certification of the ERS results and development of procedures for external monitoring of the surveying apparatus of the ISS.

— Creation of the methods for improving the information content and definition of the tasks by overlap processing of the results in various ranges of the electromagnetic waves on the basis of synergetic principles.

Taking into account the experience of the Ukrainian institutions on the use of radio physical methods for the ERS, we also propose development of on-board radar and radiometric systems with greater information content. This problem has two aspects. The first of them concerns the combined ERS active-passive method to improve the reliability of data interpretation for oceanographic and glaciological tasks. The proposed complex will have a wide survey band, devices for data processing and subsequent data transmission in the form of synchronous radar and radiometric images of the same regions of Earth. The provided modes of on-board calibration of all channels of the complex significantly increase the stability and absolute accuracy of results. The second aspect envisages creation of the two-mode radar system (RLS). We have elaborated a new approach to the RLS apparatus, based on optimization of the parameters of the designed antennas and on a wide use of microprocessor equipment.

Metrological traceability of measurements performed by the ground-based instruments, from the aircraft and satellite is one of the most difficult requirements. To meet this requirement it is necessary to reference the power scales and spectral channels of the instruments using standardized test facilities and standards by a common procedure. Hence the need for validation of space information in the specially selected ground-based testing areas. Not all the objects present in the metrological testing areas are fit to be the test objects for metrological purposes, but only those, whose spectral lines are stable enough during a certain period. Systematic observations and measurements of parameters should be performed in the testing areas, in order to record the change of state of the tested ground-based objects and related changes of the spectral characteristics. Using this approach, we have worked out a system of criteria for the testing areas and have defined the main purpose of the testing area network for the agricultural industry.

The most important part in technical embodiment of the instrumentation concept is to ensure the maximal achievable accuracy of absolute measurements. Therefore, both the preliminary matching of the tactical-technical parameters of a radio physical complex and its final specification, and the whole range of technological, design, and metrological decisions concerning the development and certification of the complex, as well as its launching into orbit and subsequent operation, should meet this requirement.

The proposed scanning radiometric complex will allow measurement of spatial distribution of the radio brightness temperatures of the Earth-atmosphere

Table 2. Required performance attributes for radar complex ISS

Performance Attributes	Space-born Radar Complex Components			
	mm-band	cm-band	dm-band	m-band
Operating mode	SLAR	SAR, SLAR	SAR	SAR
Wavelength	8 mm	3.2 cm	23 cm	2m
Emitted and received polarization	VV	VV	VV, HH, HV, VH	VV, HH, HV, VH
Field of view band, (at less)	500 km		700 km	700 km
- amplitude regime		750 km		
- SAR-regime		700 km		
Cover band			90 km	90 km
SAR-regime (at less)		90* (300)** km		
Resolution	1–2 km		10–20 m	10–20 m
- SLAR-regime		1–3 km		
- SAR-regime		5-15* m, (100–150)** m		
Contrast-background sensitivity (at less)	1 dB	1 dB (SLAR)		
Field of view number		4	4	4
Antenna type	Periodical scheme	Reflector-type	APHA	PHA
Antenna size				
movement direct	4–5m	12–15m	10m	4 m
across movement		1 m	3 m	
Antenna pattern	$cosec^2$	$cosec^2$		
Power supply				
- uninterrupted regime	150 Watt			
- on the survey (10 min)	550 Watt			
Equipment weight	200 kg			

* — focused aperture high resolution SAR-regime,

** — unfocused aperture average resolution SAR-regime

system in the six frequency intervals of the super high frequency range within the given radar scanning band. As regards the majority of its parameters, this complex is not inferior to the foreign analogs of space radiometric complexes such as the SSM/I, AMSR/AMSU in the ERS, DMSP, and NOAA systems, and is even superior to them in some parameters (see Table 2).

The complex of radio physical instruments operating in the wave range from several millimeters up to tens of meters with different polarization and spatial resolution from 2 km to 10 m, will allow not only solving the traditional problems (flood and storm monitoring, etc.), but also studying the internal geological structure of Earth.

Multi-frequency radar ERS complex will consist of 4 radar stations of lateral scanning, which are working simultaneously in the overlap scanning bands at the wave lengths of 8 mm, 3 cm, 23 cm, and 1.8 m. The radar station of 8-mm range should operate in the mode of radar lateral scanning (amplitude mode). The radar station of 3-cm range should operate in the mode of radar lateral scanning and in the mode of aperture synthesis. Other radar stations should operate only in the aperture synthesis mode. The lock-in bands of some stations depend on the operational modes and make up from 100 km to 700 km. The spatial resolution of low, middle, and high type is also dependent on the operational mode (see Table 2).

The «Surface» project pursues the following scientific objectives:

- Study of the morphology of the underlying surface of Earth by radar methods;
- Study of the dielectric properties of the underlying surface using the data of the microwave range;
- Study of the properties of the upper layer of the Ocean using the data of thermal and optical surveying and the data of dedicated research of space altimetry and gravimetry;
- Study of the ozone distribution in the atmosphere;
- Modeling the energy-mass transfer processes in the geosystems;
- Creation of a database on the general view of

Table 3. Basic requirements to the equipment and surveying conditions for Ukraine's module of International Space Station

№ Items	Objectives	Surveying equipment			
		Ranges Spatial resolution, m / Channels			Foreign analogues on Spaceship / Spaceship equipment
		visible	infrared	radio-wave	
1.	**The most essential for Ukraine's objectives are:**				
1.1.	Assessment and control of territory and water area contamination as to toxicants (radionuclides, heavy metals, pesticides, etc.) on the basis by recording of vegetation spectral anomalies in a visible range. *	8-20 / 3	-	-	SPOT-4 / HRVIR (France) IRS-1C / LISS-III (India)
1.2.	Prospecting of oil-gas deposits on the land and shelf areas by recording and interpreting of spectral, thermal, optical density anomalies in visible, infrared and radio-wave ranges.**	20-100 / 3	250 / 1 (10-12 μm)	10-2000 *** / 4 (mm, cm, dm, m)	SPOT-4 / HRVIR (France) Ocean-O / MSU-V (Russia, Ukraine) ERS-1 & 2 / AMI-SAR (ESA) [Weight 200 kg; Overall dimensions antennas 15 m × 3 m; Power supply: 150 Watt (uninterrupted regime), 550 Watt (10 min-survey); Leading Contractor: CRSE NSAU-NANU; Participating bureaus: IRE NANU, IRA NASU]
1.3.	Examination of angular structure of optical irradiation under different hydro and meteo conditions to increase reliability and accuracy of weather forecast.*	20-100 / 3 20-100 / 3	250 / 1 (10-12 μm)	-	SPOT-4 / HRVIR (France) Ocean-O / MSU-V (Russia, Ukraine)
1.4.	Examination of «supervision» effects from spaceship through the sea water mass in visible range that allows for the first time to explain this phenomenon. *	20-100 / 3 50-100 / 6	250 / 1 (10-12 μm)	- -	SPOT-4 / HRVIR (France) Ocean-O / MSU-V (Russia, Ukraine) IRS-1C / LISS-III (India)
2.	**Earth cover research**				
2.1.	Monitoring of vegetation cover condition, including plantings development dynamics and forecasting of crops yielding capacity. *	20-100 / 3 50-100 / 6	- - 250 / 1 (10-12 μm)		SPOT-4 / HRVIR (France) IRS-1C / LISS-III (India) Ocean-O / MSU-V (Russia, Ukraine)
2.2.	Ecological monitoring of condition and dynamics of development of forest ecosystem	-"-	-"-		-"-
2.3.	Monitoring of condition and soil moisture including erosion dynamics.**	-"-	-"-	10 / 3 (cm, dm, m)	ERS-1 & 2 / AMI-SAR (ESA) (For parameters of radiophysical equipment see Table 2)
2.4.	Estimation of meliorative systems condition, monitoring of swamped areas.**				
2.5.	Survey aiming to update topographic maps as well as land and water cadastre compiling*	8-20 / 3		10 / 3 (cm, dm, m)	SPOT-4 / HRVIR IRS-1C / LISS-III ERS-1 & 2 / AMI-SAR

Technology of the survey and thematic interpreting of the data acquired		Operational conditions for the survey				Projects (organizations), competing for International Space Station complement that could cooperate to solve the objectives	Departments, concerned with task accomplishment
Leading Contractor	Participating bureaus	Observation periodicity	Observation condicions	Angle of the Sun rising	Air and ground proofing		
CASRE NANU	ERRIU of Nat. Security and Defense Council, SRI NSAU-NASU	March-Oct. (1 time per 10 days)	Cloudless sky	>35°	Aerial survey from Flying Lab., sampling of vegetation in the test areas	«Inframon» (MAO NASU), «Sova» (Inst. of Physics, NASU), «Choven» (IRA NASU), «Module» (Res. Centre «Fonon»)	State Administration, Ministry of Agriculture, Min. of Forestry, State Com. for Water Manag., State Com. on Land Use, Min. of Ecology, Ministry of Emergence Situations
CASRE NANU	CRSE NSAU -NANU, MHI NASU	March-Oct. (1 time per 10 days) - The whole year round once a month	Unclouded sky - All-weather	>35°	Aerial survey from Flying Lab, ground vegetation and water sampling	-"-	Nat. JSC «NAFTOGAZ Ukrainy», Geological Survey of Ukraine, SGE «Chemomorneftegaz», JSC «Ukrnafta», Foreign oil companies
MHI NASU	CASRE NANU, CRSE NSAU -NANU	The whole year round (1 time per 10 days)	All-weather		Aerial survey from Flying Lab., ground measure-ments	-"-	State Com. on Hydrology and Meteorology, State Com. for Water Manag., Dept. of Marine and River Fleet, Hydrographic Survey of Ukraine's Min. of Defense
MHI NASU	Hydro-graphic Survey of Ukraine's Ministry of Defense	The whole year round (1 time per 5-10 days in different light conditions)	Unclouded sky		Aerial survey from Flying Lab., ground measure-ments	-"-	-"-
CASRE NASU	ERRIU of Nat. Security and Defense Council, Ministry of Agriculture	March-Oct. (1 time per 10 days)	Cloudless sky	>35°	Survey by Flying Lab., sampling of vegetation in the test areas	«Inframon» (MAO NASU), «Sova» (Inst. of Physics, NASU), «Choven» (IRA NASU), «Module» (Res. Centre «Fonon»)	Ministry of Agriculture, State Dept. of Statistics, State Administration
CASRE NASU	Ministry of Forestry, Ministry of Emergence Situations	-"-	-"-	-"-	-"-	-"-	Ministry of Forestry, Ministry of Emergence Situations, State Administration
CRSE NSAU-NASU		The whole year round (1 time per 10 days)	All-weather		Survey by Flying Lab., soil sampling in the test areas	-"-	Ministry of Agriculture, State Com. for Water Manag., Ministry of Ecology, Ministry of Emergence Situations
CASRE NASU	UkrGeodez-Kartographia	4 times a year (seasonally)	Cloudless sky All-weather	>35°	Survey by Flying Lab., location survey of test areas by GPS	-"-	UkrGeodezKartographia, State Com. on Land Use, Ministry of Forestry, State Com. for Water Manag., State Administration

Cont. of Table 3.

№ Items	Objectives	Surveying equipment			
		Ranges Spatial resolution, m / Channels			Foreign analogues on Spaceship / Spaceship equipment
		visible	infrared	radio-wave	
2.6.	Accident area monitoring.**	8-20 / 3 50-100 / 6	250 / 1 (10-12 μm)	10 / 3 (cm, dm, m)	SPOT-4 / HRVIR (France) IRS-1C / LISS-III (India) Ocean-O / MSU-V (Russia, Ukraine) ERS-1 & 2 / AMI-SAR (ESA)
3.	**Sea and ocean water monitoring: ****				
3.1.	Determination of the parameters of sea-wave spectrum and near-surface wind field.	50-100 / 6			Ocean-O / MSU-V (Russia, Ukraine) ERS-1 & 2 AMI-SAR
3.2.	Storm, squall areas detection.				
3.3.	Monitoring of energetically active interaction processes in «ocean-atmosphere», including detection and parameters determination of hurricanes, typhoons.		250 / 1 (10-12 μm)		
3.4.	Location of frontal zones, currents, upwelling, internal waves, etc.			10-2000 / 4 (mm, cm, dm, m)	(For parameters of radiophysical equipment see Table 2)
3.5.	Ecological monitoring of petroleum products pollution in marine economic zones, and liquidation of oil spills.	-"- -"-	-"-	-"-	-"-
3.6.	Estimation of fish resources in marine economic zone, and detection of ships carrying a braconnier fishing.	-"-	-"-	-"-	-"-
4.	**Marine ice, glaciers diagnostics:****				
4.1.	Age (thickness) and marine ice continuity determination.	50-100 / 6			Ocean-O / MSU-V (Russia, Ukraine)
4.2.	Determination of channels and open-water in marine ice.				
4.3.	«Ice-water» boundary ecological monitoring.		250 / 1 (10-12 μm)		ERS-1 & 2 / AMI-SAR
4.4.	Glacier debacles monitoring, detection of the early stage of blocks of ice and iceberg splitting.				
4.6.	Limnic ice condition and permafrost areas monitoring.			10-2000 / 4 (mm, sm, dm, m)	(For parameters of radiophysical equipment see Table 2)

* — Surveys will be carried out by the equipment provided by other countries and installed onboard the ISS. Ukrainian party provides techniques for calibration and verification on test proving ground and thematic interpretation of the survey results.

** — In radio-wave range surveys will be carried out using domestic equipment, calibration and verification on test proving ground and thematic interpretation of surveys results.

*** — Detailed operating characteristics of this radar complex is shown in Table 2.

the surface studied, i. e., using the SAR data and higher resolution optical data.

The «Surface» project envisages the following applied tasks:

Monitoring the surface of the sea and ocean

— Analysis of the field of the wind near the water and parameters of the roughness spectrum;
— Revealing the storm and tornado zones;
— Control over energy interactive processes in the ocean — atmosphere system, i. e. revealing, monitoring and measuring the parameters of hurricanes and typhoons;
— Revealing the frontal zones, currents, and internal wave manifestation, etc.;
— Ecological monitoring of the marine economic zone; revealing the pollution by oil products and ensuring their liquidation;
— Revealing the shoals of fishes and estimation of fish reserves in the marine economic zone; detection of the poacher fishing-boats;

Technology of the survey and thematic interpreting of the data acquired		Operational conditions for the survey				Projects (organizations), competing for International Space Station complement that could cooperate to solve the objectives	Departments, concerned with task accomplishment
Leading Contractor	Participating bureaus	Observation periodicity	Observation condicions	Angle of the Sun rising	Air and ground proofing		
		The whole year round (1 time per day)	Cloudless sky All-weather		Survey by Flying Lab. On-land certification of the survey results	-"-	Ministry of Emergence Situations, State Administration
MHI NASU	CRSE NSAU-NASU	The whole year round (according to users requests)	Cloudless sky All-weather	>35°	Survey from Flying Lab. and ship's measure-ments	«Inframon» (MAO NASU), «Sova» (Inst. of Physics, NASU), «Choven» (IRA NASU), «Module» (Res. Centre «Fonon»)	Dept. of Marine and River Fleet, Ministry of Ecology, Ministry of Fishery, State Com. on Hydrology and Meteorology, State Administration
-"-	-"-	-"-	-"-	-"-	-"-	-"-	-"-
-"-	-"-	-"-	-"-	-"-	-"-	-"-	-"-
CRSE NSAU-NASU	MHI NASU	The whole year round (according to users requests)	Cloudless sky All-weather	>35°	Survey from Flying Lab and ship's measure-ments	«Inframon» (MAO NASU), «Sova» (Inst. of Physics, NASU), «Choven» (IRA NASU), «Module» (Res. Centre «Fonon»)	Dept. of Marine and River Fleet, Ministry of Ecology, Ministry of Fishery, State Com. on Hydrology and Meteorology, State Administration

— Search of the potential oil and gas bearing areas in the shelf zone.
—

Diagnostics of the marine ice and glaciers

— Determination of the age (thickness) and solidity of the marine ice;
— Detection of the channels and patches of ice-free water in the ice;
— Ecological control of the «ice-water» line;
— Monitoring the ice motions; detection of the splits of ice-floes and icebergs at an early stage;
— Monitoring the state of freshwater ice and permafrost zones.

Study of the topsoil

— Monitoring the state of vegetation topsoil, i. e., the dynamics of development of agricultural crops; prognostication the crop yield;
— Monitoring the state of soils and its mineralization and moisture, i. e. dynamics of soil eroding;

— Analysis of the state of meliorated systems; control of the swamping lines;
— Ecological monitoring of the state and dynamics of development of the timber ecosystems;
— Subsurface sensing of the arid areas; control over the processes of desertification; study of the manifestations of geological and hydrogeological structures;
— Survey for mapping the territory (more precise definition of the topographic maps) and for the land, timber, and aquatic cadastre;
— Monitoring the regions of emergencies.

We envisage the following tasks as the most urgent ones for study from the ISS:

— Estimation and monitoring of pollution of the Earth water area and surface by toxicants, radio nuclides, heavy metals, herbicides, etc. on the basis of recording the spectral anomalies of vegetation, i. e. for the Chernobyl zone and the Black Sea;

— Search for the oil and gaseous fields on land and in the shelf zones by recording the spectral and thermal anomalies of the underlying surface;

— Analysis of angular structure of optical radiation under various hydrometeorological conditions;

— Study of the «supervision» effect (space observations of locations of some underwater mountain ridges and mountains situated at the depth of several kilometers), which is explained hypothetically by variation of the transparency (color) of the subsurface layer of water at a depth of several tens of meters;

— Study of the radar and optical contrasts in the regions of the atmospheric and sea fronts;

— Study of the meso-scale structure of the field of wind and roughness in coastal regions.

The main requirements to the on-board surveying instruments of the ISS and satellites are given in Table 3.