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POSIBILLITIES FOR REMOTE SENSING AND MONITORING OF BALKAN REGION

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The present work discusses the development of a remote sensing component (the space, air and the ground segment) of an early warning system related to the control of oil and industrial pollution of the Black Sea coast at regional level.

The number of both cargo traffic (Fig. 1) and energy suppliers in Black Sea aquatoria (Fig. 2) is increasing continuously. The industrial growth of the Black Sea area and the globalization processes will accelerate further these trends in the future. The planned layouts of the *South Stream, Nabucco* and *Bourgas-Alexandroupolis* pipelines confirm that. The oil-tanker traffic across the Bosphorus is nearing its maximum. Therefore, observation and early warning of oil spills and possible averages is becoming an important element of the coastal strip environmental protection and National Security.

Fig.1

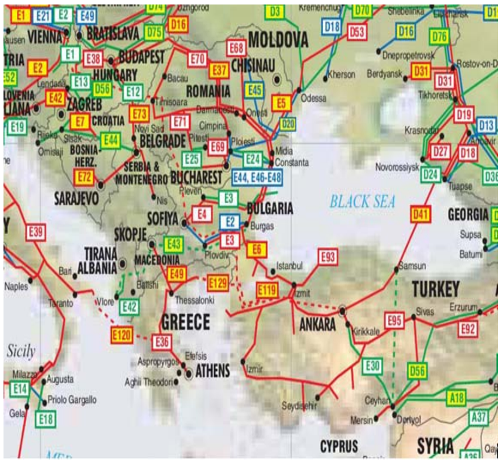

Fig. 2

The dynamic nature of the coastal processes, oil pollution, and averages require frequent observations to analyze the occurring impacts and changes.

Remote sensing methods, the technology of the small satellites, video spectrometers, and radars with synthetic aperture allow building effective systems for regional observation by several platforms.

Satellite data could be used at different levels such as early detection, evidence and security assessment.

The additional combination of coast samples analysis and inspections done by UAV-s would provide to estimate with great precision the environmental condition.

The operational approach toward development of a remote sensing component (space, air and ground segment) of an early warning system includes both observational and informational subsystems. The lack of a system for rapid informational distribution and supply at National (regional) level represents a significant problem. Data exchange and data set collection regarding events (averages) is another problem. The lack of end users' direct access to the data provided by remote sensing methods decreases additionally the progress and the efficiency.

The effective satellite observations provide to analyze the parameters and the event (pollution) spot as well as the effect of environmental pollution and restoration compensations.

On such basis, the national monitoring concept involves complex use of space and air observation methods which include:

- aerospace center for information receiving;
- satellite segment;
- air segment.

The careful consideration and analysis of some of the potential satellite systems, which could provide space observations, results in the following findings [7]:

- the only available images free of charge are provided by the US research satellites *Terra* and *Aqua* passing over about 1-2 times per day. However, their spatial resolution is 250, 500, 1000 m within the visible and infrared spectral range.
- the satellites *Monitor–3, Spot–4, IRS–P5, IRS–P6,EROS–A, EROS– B* and *RADARSAT – 1* have relatively much better spatial resolution (from 0.7 to 40 m) but less cyclic recurrence (excluding *RADARSAT*) of the passage over the same territory which is a disadvantage;
- the prices of the observations received are much bigger and determined by the value of the licenses issued by the operators as well as the streamlining of the reception complex's base organization.

Judging from the above conclusions, it is obvious that it is advisable to resolve the tasks for real or near-real time operative monitoring using the satellites *Terra* and *Aqua* since the observations received there from are free of charge and the cyclic recurrence of their passage over the same territory is the most suitable one. The low space resolution in this case could be indicated as a major shortcoming.

The base configuration of the center allows data receiving by the satellites *Terra* and *Aqua*. Receiving images and data from other satellites, however, requires additional software and shall be performed upon request. The cost of the license, the amount of received data, and the procedures of interaction with the space systems' operators shall be negotiated on signing the contract for the complex's supply.

On initiative of the Space Research Institute, at the Ministry of Emergency Situations, Aerospace Monitoring Center was established (Fig. 3).

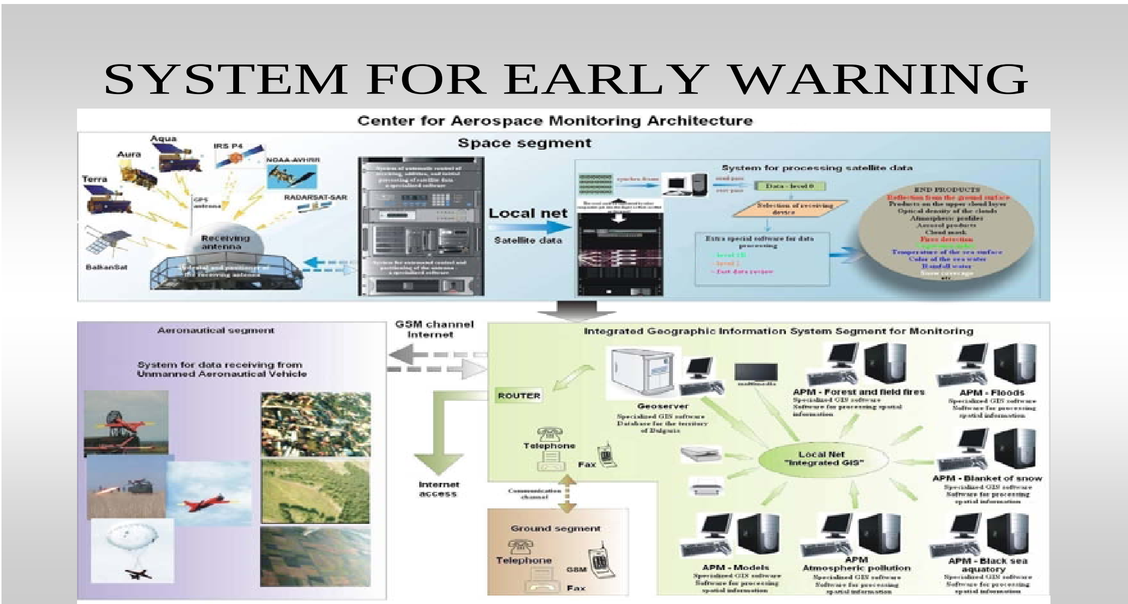

Fig.3

The centre's topical orientation is shown in Fig. 4.

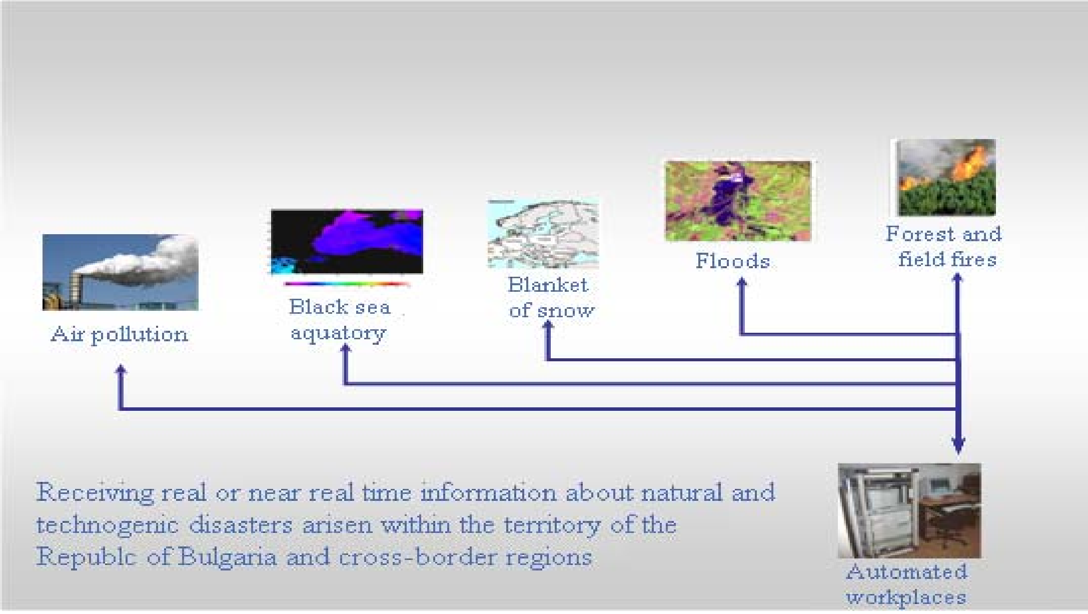

Fig. 4

At SRI-BAS, investigations are carried out based on the information received by the satellites *Terra* and *Aqua* providing to monitor on a daily basis the atmospheric pollution in the Municipalities of Bourgas, Stara Zagora, and Kurdzhali.

Fig. 5

The *Direct Broadcast* regime of the MODIS instrument onboard the NASA satellites *Terra* and *Aqua* allows ensuring good temporal coverage. In addition, the specificity of the *Terra* and *Aqua* orbits allows good temporal coverage under various light conditions. *Terra* passes over at about 7h30min UTC (coordinated universal time) and 18h30min UTC, respectively, while *Aqua* passes over 2 hours later.

The MODIS instrument has 36 optical channels covering from 0.4 up to 14.4 μm from the visible to the infrared range at resolution of 250, 500, and 1000 m regarding the different groups of channels. Data obtained through MODIS are used for various applications in accordance with the method NASA has suggested to study regional and global environmental changes. In order to carry out operative analysis, the combinations at higher resolution K2K1K1 at 250 m and K1K4K3 appear to be useful. At the same time, algorithms for increasing the resolution from 500 to 250 m are employed alongside with some more specific biophysical parameters to estimate sea surface, dry land, atmosphere, and temperature parameters of the land.

The use of infrared channels allows fires to be analyzed (Fig. 6, 7) at different stage and resolution. The latter must have higher value regarding the *Dry Land*, *Clouds*, and *Aerosols* groups. The thermal infrared products are generated by means of data obtained at day or night at lower resolution of 1000 m.

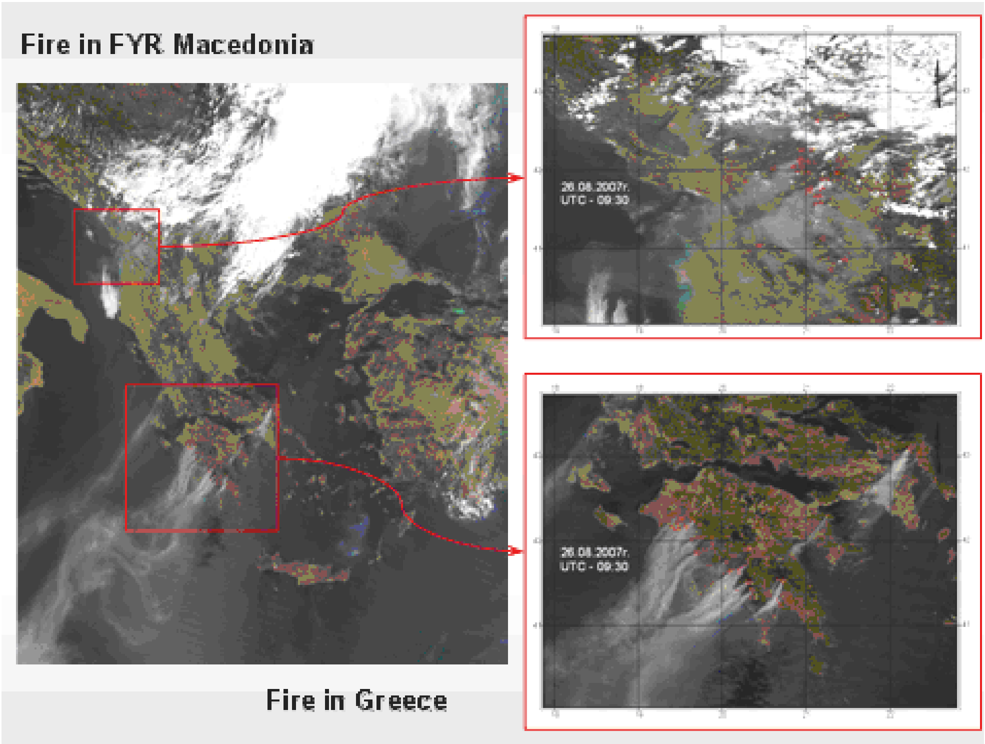

Fig. 6

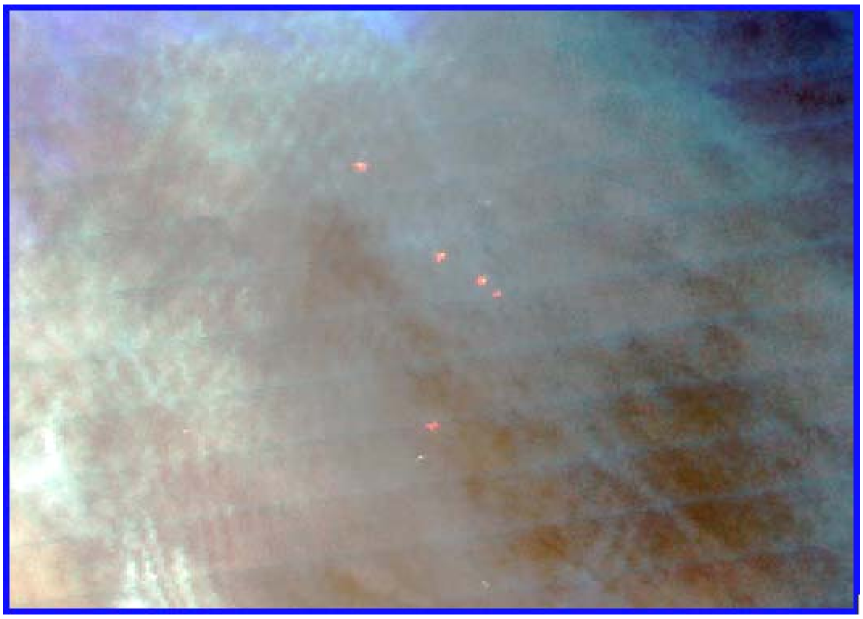

Fig. 7. Hot spots: gas combustion on sea platforms, MODIS, level 2A, K721, thermal anomalies, resolution 500 m

Depending on the cloud coverage, the data received through MODIS DB in real time allow the seacoast to be analyzed at time scale almost equal to the real one. The products at level 1B, 2 are generated up to 1 hour after either *Terra* or *Aqua* has passed over.

Level 1B, products HDF format – 20 min after telemetry

Level 2A, products Geo, TIFF format, 10 min after Level 1

Most of the coastal security depends on monitoring oil pollution and averages in the presence of intensive transport pattern, tankers, the *South Stream* and *Bourgas-Alexandroupolis* pipelines etc. Regardless of the purpose of MODIS (global observation of the Earth's surface and the World Ocean), the group of channels operating at resolution of 250 m could be used successfully to detect medium-sized oil spills in relatively clear weather and appropriate wind speed. The local host station provides the unique opportunity to observe on a daily basis the aquatic environment of the Black Sea and the coastal area.

Cooperation with port authorities to receive operational details by the passing vessels/traffic will substantially increase the system's efficiency. Using the Coast Guard will help to establish and maintain a database of coastal features and anthropogenic processes.

Crucial examples of observing aquatic environments in real time are oil spills (Fig. 8), averages, and plankton behaviour/density. For anthropogenic purposes, other channels and products of MODIS could be used.

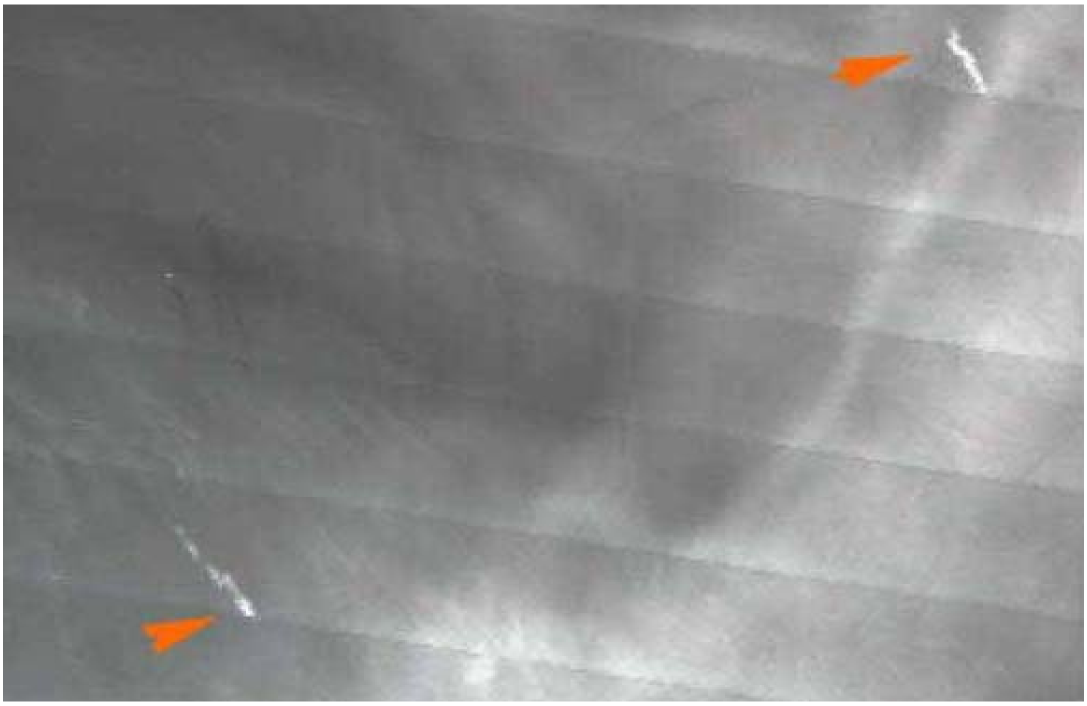

Fig. 8 Subtle oil spills on the sea surface, level 2A K211, resolution 250 m, *Terra*, the red arrows point to the oil trails/spots

The hyper spectral analysis of the sea surface is more difficult to implement and requires more parameters than it does in case of soil and plant cover. The little reverberating ability of the water within the red and infrared range set the pattern for it as well as the dynamics of the *water – atmosphere* margin. The big sizes of the pixels of the thermal channels impede its use for operative purposes.

C cloud cover and night time require previous placement of operational orders for radar images received by SAR, RADARSAAT, ENVISAT, ASAR, etc. to allow details of the spills to be analyzed at both day and night time regardless of the weather (Fig. 9).

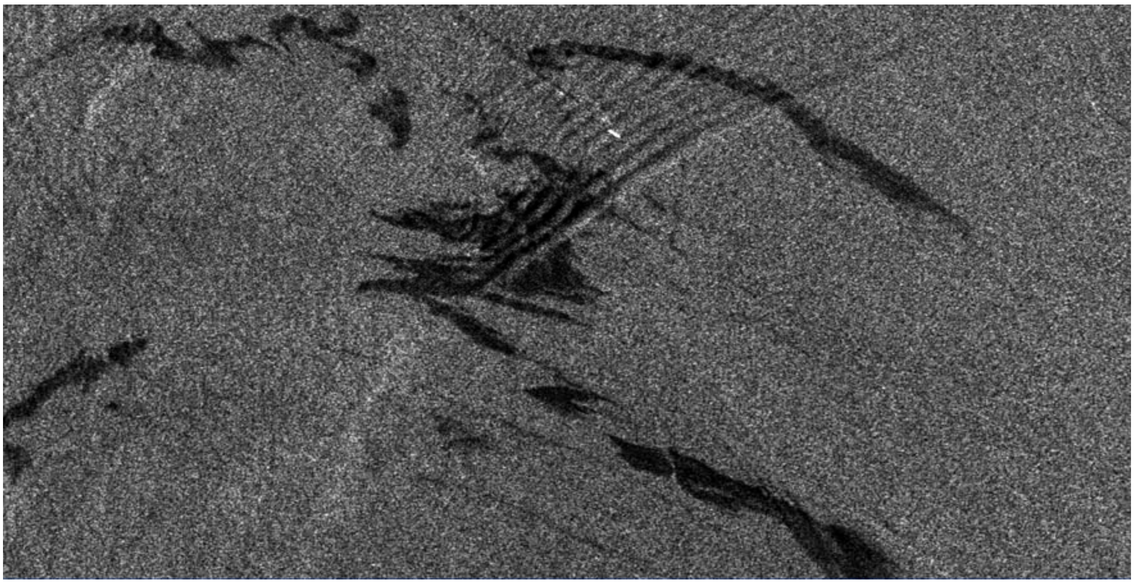

Fig. 9. Oil spill, RADARSAT 1, Fine Mode, C band.

To establish a comprehensive monitoring system, improvements in the spatial resolution, temporal resolution, and operation in cloudy weather (day and night) are required.

The small satellites intended for carrying out regional tasks appear to be a suitable complement to the existing global systems, thus aiming at building an Early Warning and Monitoring System for oil thoroughfares within the sea and in the coastal regions, accounting for the modern trends of preferable usage of small satellites, Fig. 10.

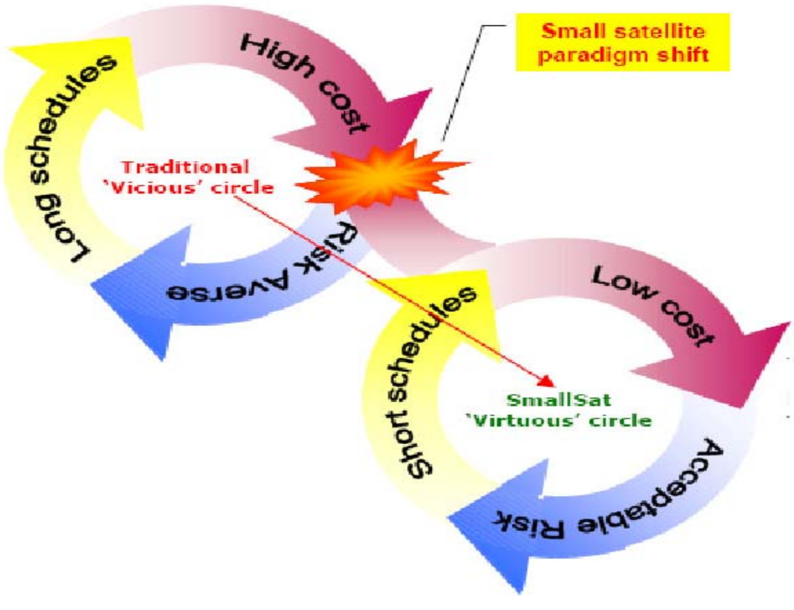

Fig. 10

The most decisive factors dominating this choice are:

- considerably lower cost;
- considerably shorter period of construction and manufacture;
- lower weight which affects the requirements to be met by the transport systems and reduces greatly the price of launching into orbit. This might be essential in case of launching into geostationary orbit or interplanetary missions (Fig. 11).

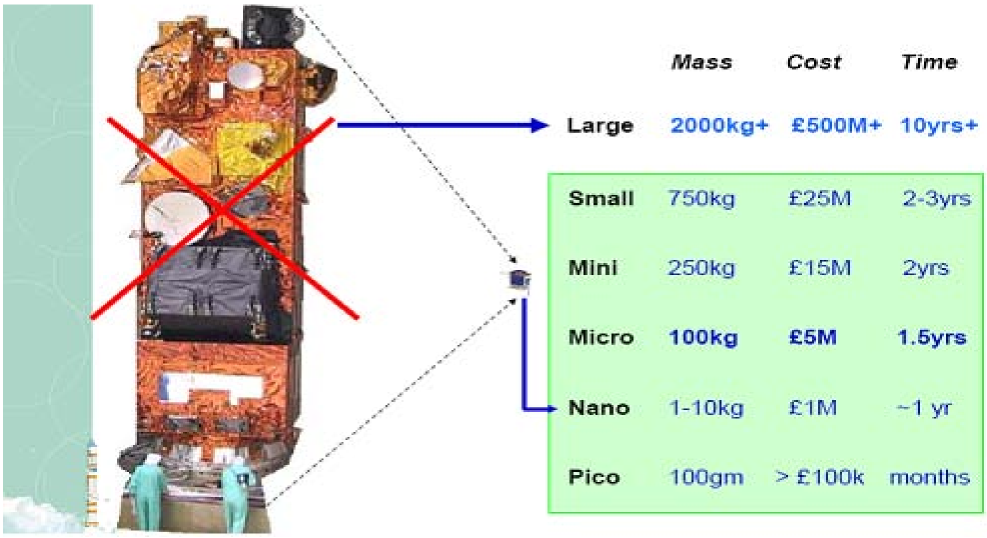

Fig. 11. Satellite platforms, mass, price, time of the program
A constellation of several small satellites could not only embrace the Black Sea zone but also include countries from the Mediterranean and Central Europe.

The sequence of the equipment's use might involve the following phases:

- phase 1A: multi-hyper spectral camera with additional thematic processing;
- phase 1B: second pattern of Type 1A;
- phase 2: small satellite, radar with synthetic aperture.

The temporal and spatial resolutions for the various applications of remote sensing methods are shown in Fig. 12.

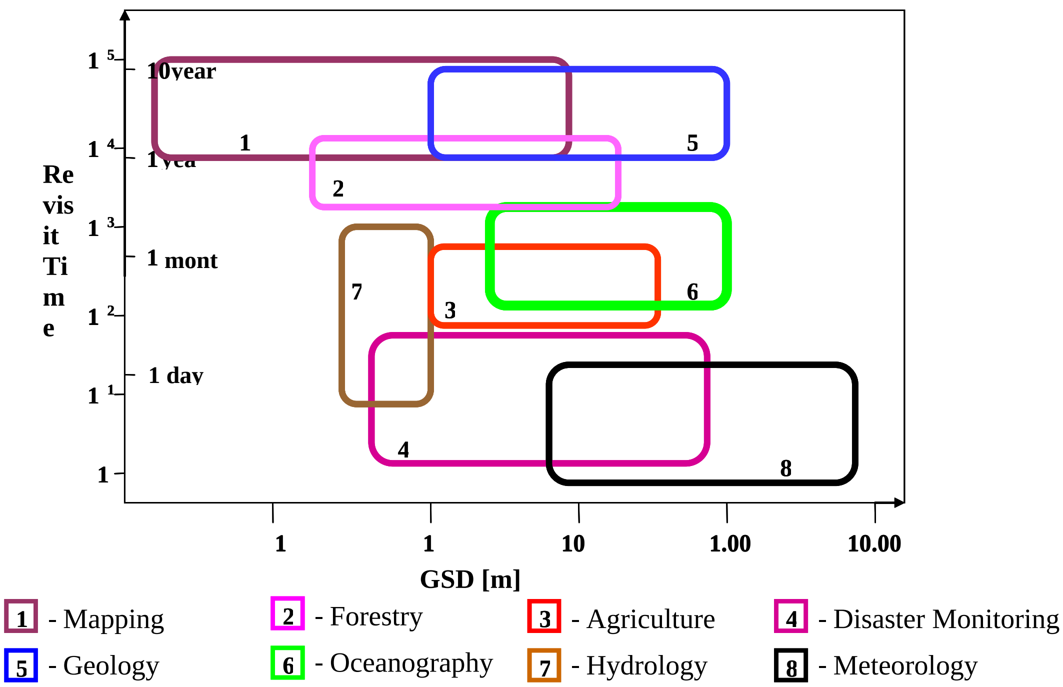

Fig.12

Oil spills and averages are covered by area 4.

In the Space Research Institute, BAS, the BALKANSAT Topic is being developed, providing for theoretical rationalizing and practical development and implementation of the satellite [10].

Based on the investigations performed so far, we may conclude that this satellite should weigh between 10 and 100 kg, i.e. a microsatellite is needed (small satellite in Bulgarian) (Fig. 13) [11].

Fig. 13

The major characteristics of the satellite are shown in Fig. 14.

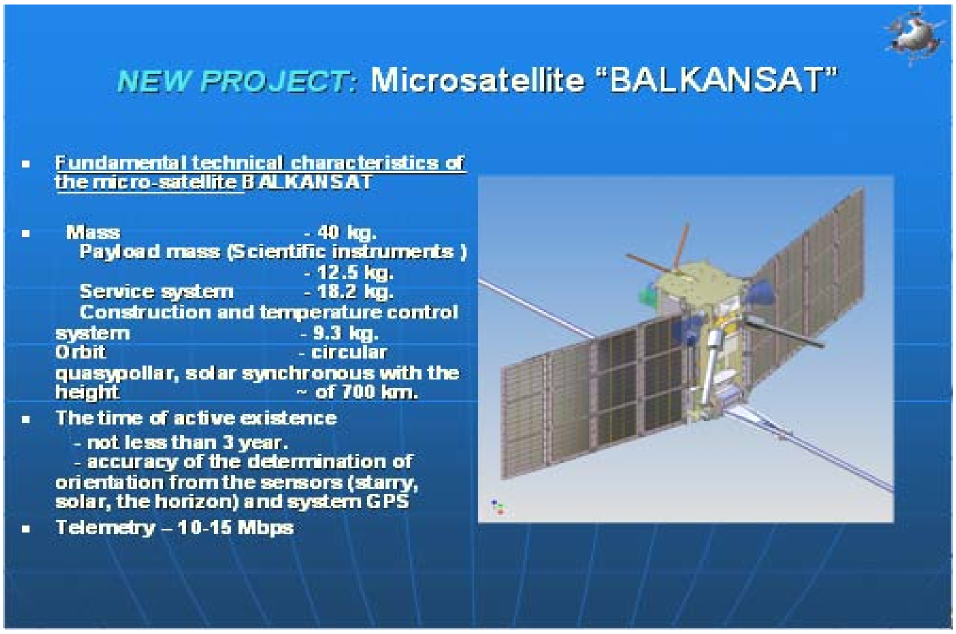

Fig. 14

Additional *in situ* information obtained through both manned and unmanned aerial vehicles could improve vastly the operative abilities of the National Monitoring System and increase identification possibility. The most common classification of the US UAVs is shown in Fig. 15.

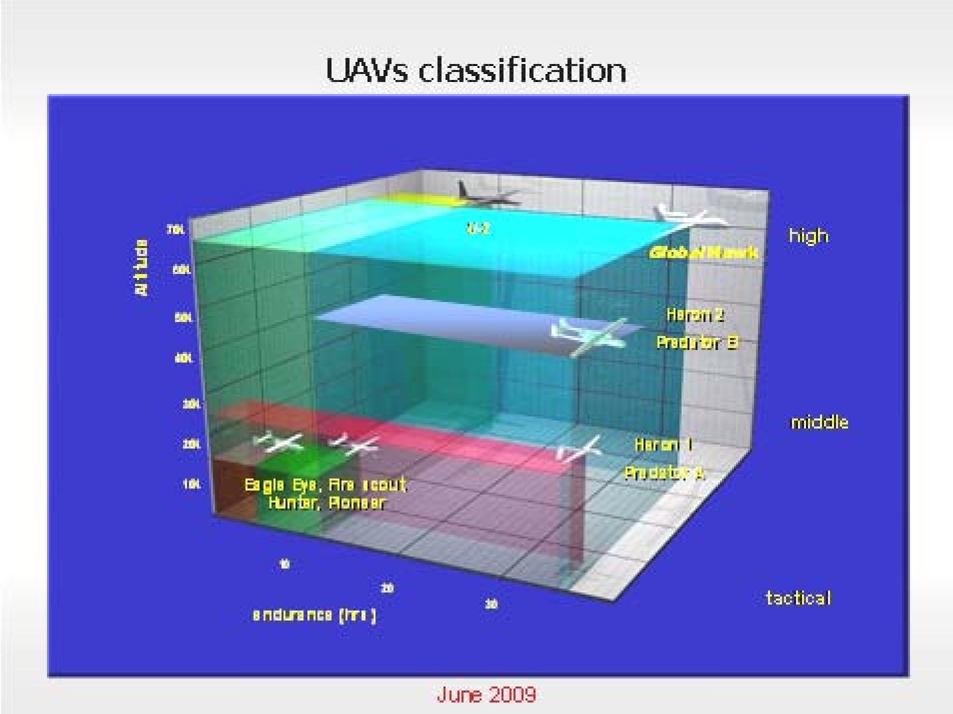

Fig. 15

Accounting for the small territory of Bulgaria, light UAVs could be used (Fig. 16) equipped with onboard video system operating within the visual and near infrared range at spatial resolution less than 50 cm.

Fig. 16

Accounting for the operational range of the current UAV (50 km), the territory of the country could be divided into 6 operational zones (Fig.17).

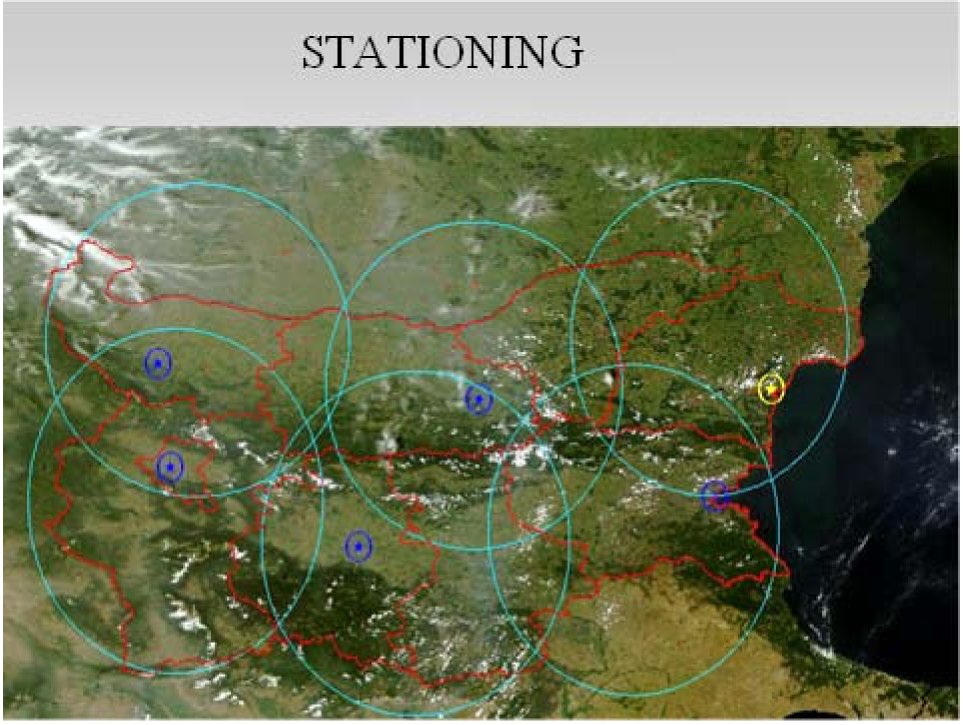

Fig. 17

The various degree of smoothness of the sea surface at different levels of oil pollution could be analyzed within the optical range as well by means of an airplane (Fig. 18).

Fig. 18. *In situ* observation of the sea surface, oil pollution

The development of the National Monitoring System does not diminish Bulgaria's willingness to take part in international programs and projects related to environmental monitoring and security, as evidenced by the GMES European project (Fig. 19).

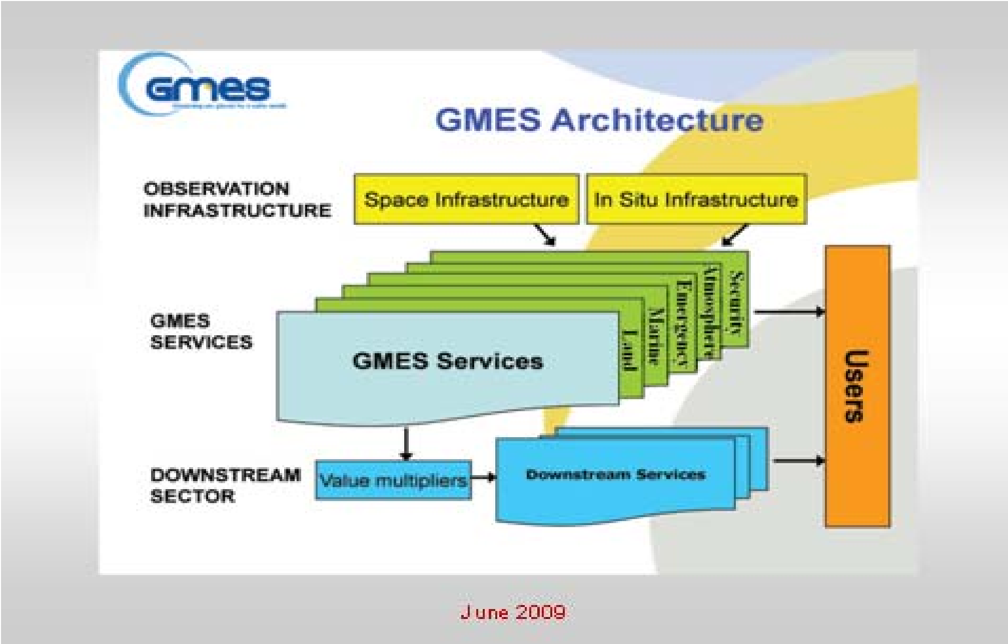

Fig.19

NATO's AGS are of interest to us, which determines the cooperation under the TIPS project, Fig. 20.

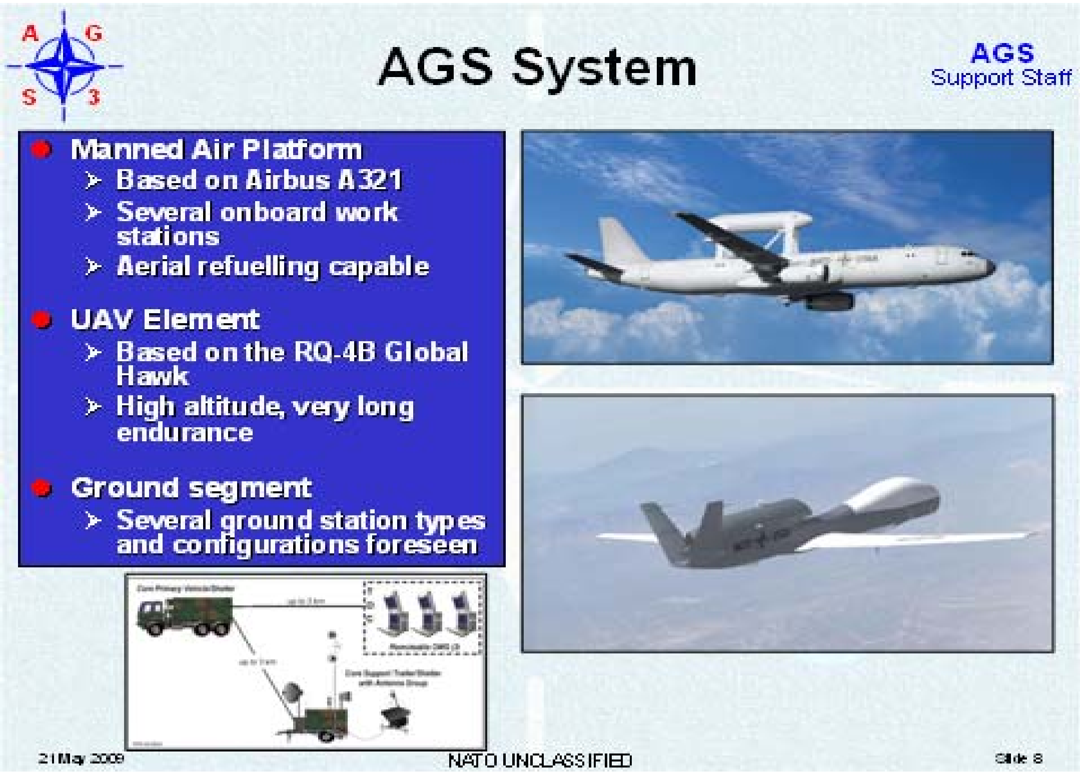

Fig. 20

Conclusions

1. Aerospace monitoring has no alternative in forming impartial attitude toward environment condition and security.
2. The development of National Aerospace Monitoring Systems is part of the common efforts to provide efficient mechanism for prevention and mitigation of various kinds of crises, whenever possible. Elsewhere, these could cooperate to abate their consequences and the number of people suffering.

3. The Bulgarian institutions must provide the required premises to enable the participation of the Bulgarian scientific and research community, private business and industry in the big European and NATO projects related to global monitoring systems.
4. The Government of the Republic of Bulgaria must undertake the required steps to provide for Bulgaria's full membership in the European Space Agency.

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