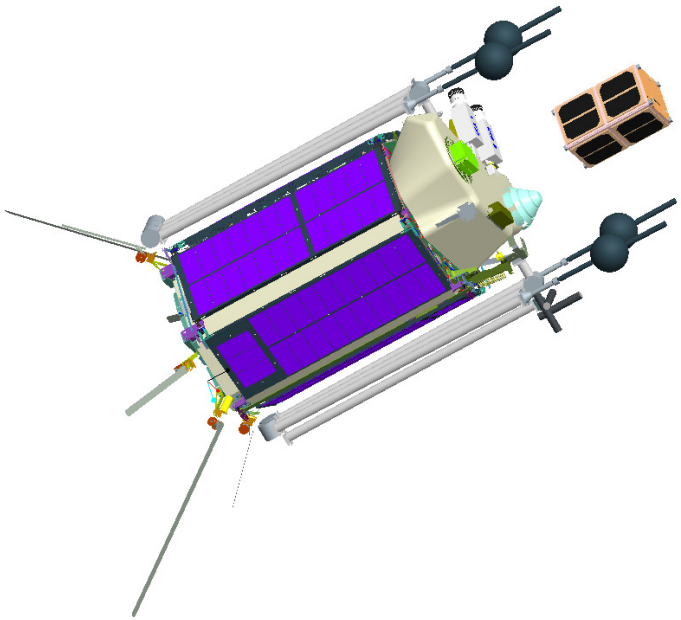
MARSH

LEADERSHIP, KNOWLEDGE, SOLUTIONS...WORLDWIDE.

TWINSAT
Presentation to Insurance Community



GEOSCAN Technologies

MARSH & McLENNAN COMPANIES

TWINSAT
Key Facts

Objectives

- Development of integrated aerospace and ground technologies for detection and monitoring of earthquake precursors (Step 1)
- Launch of a space demonstrator – testing its efficiency for short-term earthquake forecasting (Step 2)
- Deployment of an operational satellite constellation and supporting aerial and ground based networks for prediction, monitoring and mitigation of large-scale natural disasters (Step 3)

Contributors

- GEOSCAN Technologies and Coordination Forecasting Center of the Institute of Physics of the Earth, Russian Academy of Sciences (IPE RAS)
- Mullard Space Science Laboratory (MSSL) of University College London (UCL) in collaboration with SSTL

TWINSAT
Key Facts

Timeframe

2012 – 2014 for Step 1

2014 – 2017 for Step 2

2018 – 2021 for Step 3

Main project features

– Operational TwinSat system will comprise space, aerial and ground segments

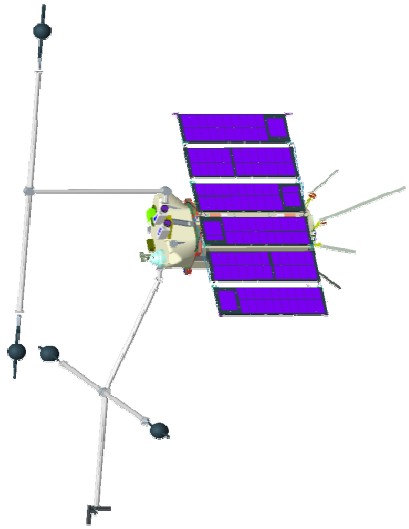
– measurements will be made from twin (master / slave) satellites orbiting in controlled formation at 700km altitude

TWINSAT
Key Facts

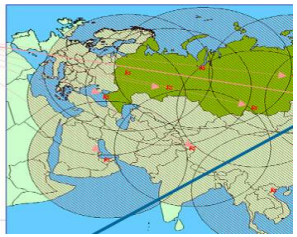
Main project features

3-levels system and multi-parametric analysis of wide variety of precursor signals detected synchronously through diverse methods in different media substantially increases accuracy and reliability of earthquake prediction

Space segment constellation of the micro/nano satellite pairs for EM and plasma measurements (TwinSat-EP) and remote sensing microsatellites (TwinSat-RS)



Airborne segment airborne laboratories and tethered balloons operating in seismic and volcano regions



Ground segment – network of geophysical stations in seismic zones and complete ground infrastructure providing operation of the system as a whole and delivery of an early warning service

TWINSAT
Products

Type of products provided by the operational TwinSat System

– Short-term precursor signal information service delivered to Coordination Forecasting Center, national/regional organizations and authorities responsible for earthquake prediction and distribution of warning (alarm) signals

– Data bases from space, airborne and ground segments made available to insurance companies, scientific, ecological, security and other organizations and private subscribers in various countries

As a by-product the following information will be available

– Flood and fire imaging

– Regular data on solar and geomagnetic activity and forecast of health affecting geomagnetic storms

– Data on radioactive and chemical pollutants

TWINSAT
Products

Five categories of products are envisaged

– Raw data from some instruments (on demand of customer)

– Data packages from space, aerial and/or ground segments (on demand of customer) related to specific regions and periods of time

– Full data package

– Results of dedicated (thematic) data processing with identification of precursors to earthquakes and volcano eruptions and possible effects of technological impact on atmosphere and ionosphere and other phenomena (on demand of customer)

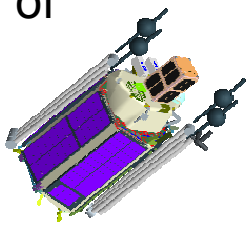
– Short-term forecast of large-magnitude earthquakes and volcano eruptions

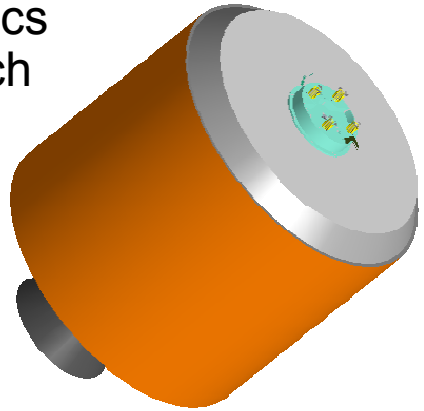
Access to defined data sets (quick look information) in graphic form will be available on the Internet

TWINSAT
Contributors

GEOSCAN Technologies (GT), Moscow, Russian Federation

- Created in October 2004
- R&D in space technologies and telecommunications, geophysics and space science mainly through commercial contracts with Russian and foreign state enterprises and private companies and research projects of the International Science and Technology Center
- Since October 2011 resident at the Skolkovo Innovation Center (cluster of Space Technologies and Telecommunications) with the project “An application of micro and nano satellites for detection and monitoring of earthquake precursors”
- GT oversees development of the TwinSat microsat platform with its payload and a series of specialized nano and pico spacecraft
- Cooperation with Schmidt Institute of Physics of the Earth and Institute of Space Research of Russian Academy of Sciences
- Close ties with leading space enterprises





TWINSAT
Contributors

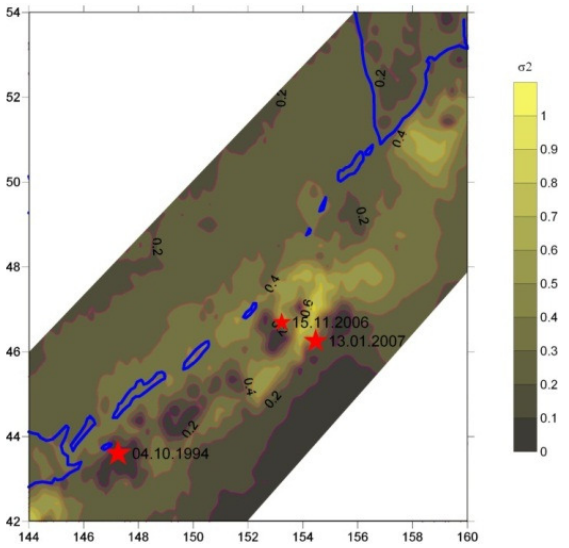
Mullard Space Science Laboratory (MSSL) – Department of Space and Climate Physics, University College London

- Leading world research organization and largest space laboratory in the Universities of Great Britain, established in 1966
- Participation in 35 satellite projects with its instruments and more than 200 rocket experiments
- Research in cosmology and physics of extra galactic objects, physics of the Sun and planets with the satellites, physics of the Earth and near Earth space
- Development of state-of-the-art technologies and payload instruments for space research, including new generation devices with unique miniaturized size, mass and power consumption, for application on micro and nanosats
- Close collaboration with SSTL, leading satellite manufacturer with world-class expertise in both small satellite platform technology and imagers
- SSTL potential participation on TwinSat : shared production of microsatellites and design of satellite constellation, satellite operations

TWINSAT
Contributors

Coordination Forecasting Centre (CFC), Moscow, Russian Federation

- Branch of Schmidt Institute of Physics of the Earth, Russian Academy of Sciences
- Established in 2006
- Main function is to coordinate earthquakes forecasting in the whole territory of Russian Federation and adjacent countries and develop new methods for comprehensive analysis of earthquakes precursors of different nature
- Collaborates with GT, seismological centers of China, Armenia and Azerbaijan, Geophysical Survey of the Russian Academy of Sciences and the National Centre of Management of Crisis Situations of the Russian Emercom



CMT-solution variations (compiled by CFC,2006): Kuril-Kamchatka Region earthquake forecasting

TWINSAT
Project Financing

Current status on project financing

- Skolkovo Foundation grant (“0” stage) for the development of innovation project: “An application of micro and nano satellites for detection and monitoring of earthquake precursors (TwinSat project)”
- UK Technology demonstration on orbit of electron sensor – 2012 to 2013 (approved)
- UK Demonstration on orbit of TwinSat-1N prototype as part of QB50 – 2014 (approved)

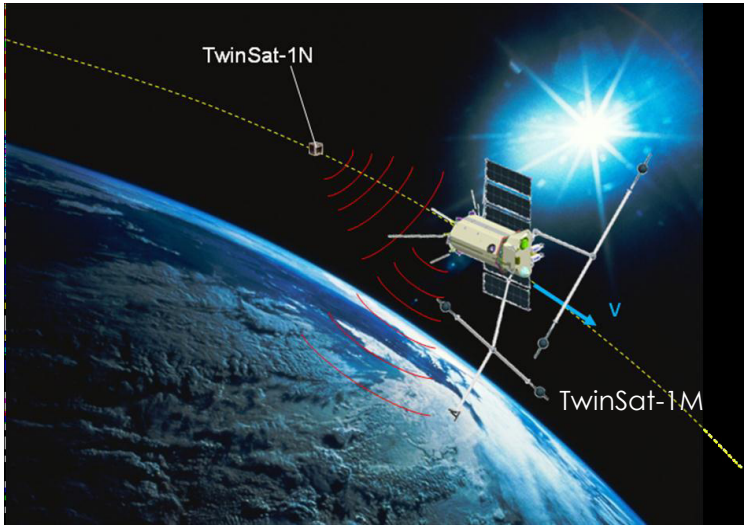
Next stages

- Skolkovo Foundation grant (“seed” stage, 75%) and the co-investment (25%) from an external source – Timeframe 2012 to 2014
- Skolkovo Foundation grant (“early” stage, 50%) and the co-investment (50%) from an external source – Timeframe 2014 to 2017
- Skolkovo Foundation grant (“advanced” stage, 25%) and external financing (75%) – Timeframe 2018 to 2021
- UK TwinSat-1N flight sample production – 2014 to 2017 (UKSA/TSB, to be approved)
- UK Support to data analysis -2018 to 2021 (NERC)

Opportunities for external financing are open

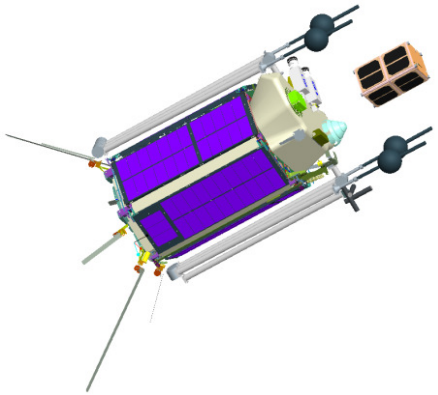
TWINSAT
A Russia-UK Cooperation

An application of micro and nano satellites for early detection and monitoring of earthquake precursors



TwinSat-1 Demonstrator

Two master/slave satellites, TwinSat-1M microsat and TwinSat-1N nanosat, operating at a controlled inter-satellite distance



Operational system

Space segment

Airborne segment

Ground segment

3-levels system and multi-parametric analysis of wide variety of precursor signals detected synchronously through diverse methods in different media substantially increases accuracy and reliability of earthquake prediction

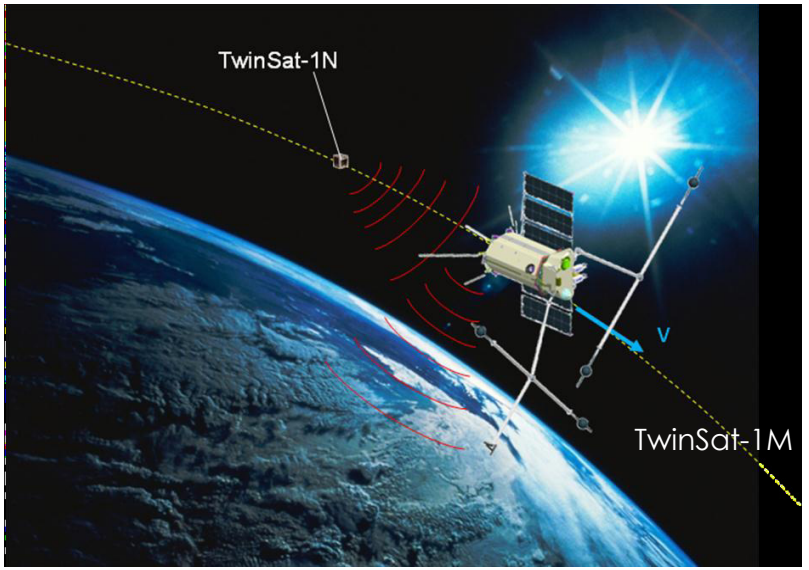
Project leaders:

Dr. Vitaly Chmyrev
GEOSCAN Technologies
Inst. of Physics of the Earth
Russian Academy of Sciences

Prof. Alan Smith
Mullard Space Science Laboratory (MSSL)
University College London

TWINSAT
Technical Outline

1. Demonstrator space mission (*TwinSat-1*) to study correlation of space and ground-based observations and optimize the ability to distinguish earthquake precursor signals from signals of non-seismic origin



- Two platforms (master/slave) - TwinSat-1M microsat and TwinSat-1N nanosat operating at a controlled distance
- Inter-satellite radio link for data exchange
- TwinSat-1M equipped with propulsion thrusters to ensure mutual visibility zone at a distance ≤400km
- For proposed Sun synchronous orbit, revisit time over a specific region will occur approximately 5 times over a two day period
- Expected number of earthquakes with magnitude 6 to 6.9 on the Richter scale monitored by the system is ~400 over a 3 years period
- Focus on the Kuril/Kamchatka region for deployment of a multi-discipline ground network (most active seismic region in the world)

TWINSAT
Technical Outline

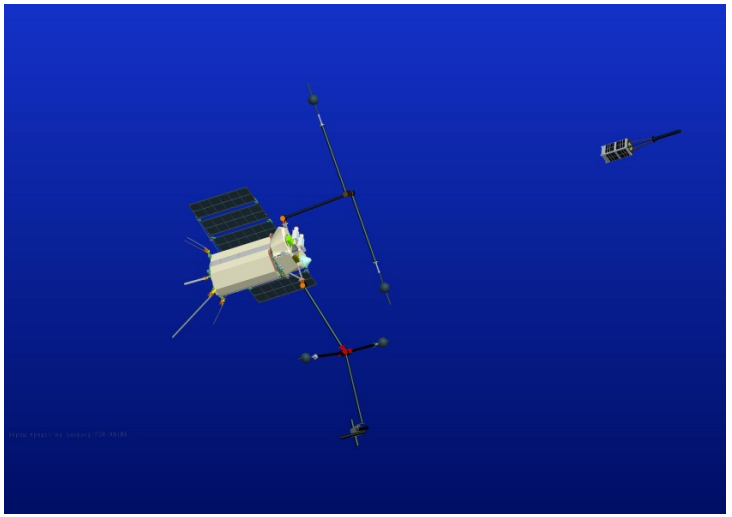
1. Demonstrator space mission (*TwinSat-1*)

TwinSat-1M characteristics

Satellite dimensions (without booms)	Ø46 x 53 cm
Mass (including payload)	~50 kg
Power - Average - Maximum	 90 W 140 W
TwinSat-1N separation velocity - Linear - Angular	 3 cm/s < 6 deg./s (TBD)
Attitude Control	3-axis, 8 arc min stability
Orbit	Sun-synchronous, altitude 700-800 km, ~100min period
Telemetry to ground - Fast channel (8.2 GHz)	 ~60 Mbit/s
Onboard memory	> 5 Gbyte
Inter-satellite link freq.	~2.4 GHz
Active lifetime	>3 years

TwinSat-1N characteristics

Dimensions	10 x 10 x 22.7 cm
Mass	2.5 kg
Power - Average - Peak	 2.2W 4.0W
Attitude control	3 axis stabilized, ~1^0 accuracy
Inter-satellite link frequency	~2.4 GHz
Telemetry to TwinSat-1M - Fast channel	 64 Kbit/s
Telemetry to Ground - Slow channel (145/435 MHz)	4.8 Kbit/s
Active lifetime	>3years



TWINSAT
Technical Outline

1. Demonstrator space mission (*TwinSat-1*)

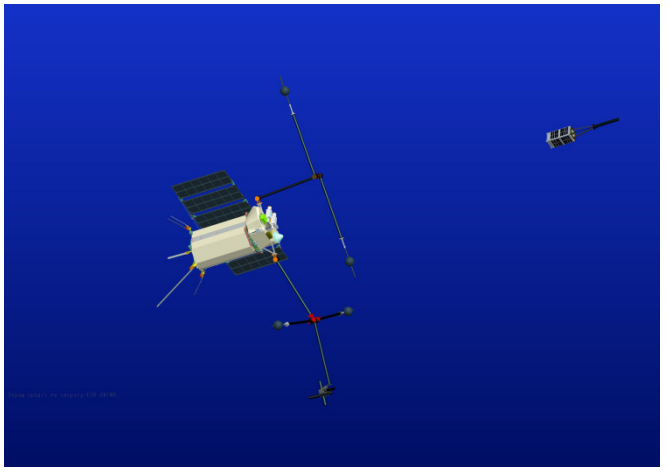
Basic parameters to be measured by the TwinSat-1M spacecraft

- DC electric field vector
- Spectral and wave characteristics of 6 electromagnetic field components in ULF/ELF range (0.5 – 500 Hz)
- Spectrum and sample waveforms of electric field oscillations in VLF/LF (0.5-300 kHz) range
- Amplitude and phase variations of ground based VLF/LF transmitter signals
- Spectrum and sample waveforms of electromagnetic waves in VHF range (22 – 48 MHz)
- Variations of thermal and supra thermal (0.3 - 20 eV) plasma parameters
- Energy distributions of electron and ion fluxes with energies 0.3 – 300 eV for two directions
- Lightning activity in the sub-satellite regions (optical measurements) – needed to discriminate against lighting-related events
- Structure of optical observations including measurements of outgoing long wave (8-12 microns) radiation intensity to be determined.

Basic parameters to be measured by the TwinSat-1N spacecraft

- Variations of thermal and supra thermal (0.3 – 20 eV) plasma parameters*
- Energy distributions of electron and ion fluxes with energies 0.3 – 300 eV for two directions*
- Wave form of ULF/ELF magnetic field oscillations (0.5 – 500 Hz), one or two components

* TwinSat-1M and TwinSat-1N instruments have the same design



TWINSAT
Technical Outline

2. Operational satellite constellation with airborne and ground based networks for forecasting and mitigation of large-scale natural disasters

Space constellation

Estimated 6 remote sensing micro satellite **TwinSat-RS** and 6 micro/nano satellite pairs **TwinSat-EP** for electromagnetic and plasma measurements in the ionosphere at SS orbits ~700 km altitude

Design of the satellite constellation will be defined on TwinSat-1 demonstrator results

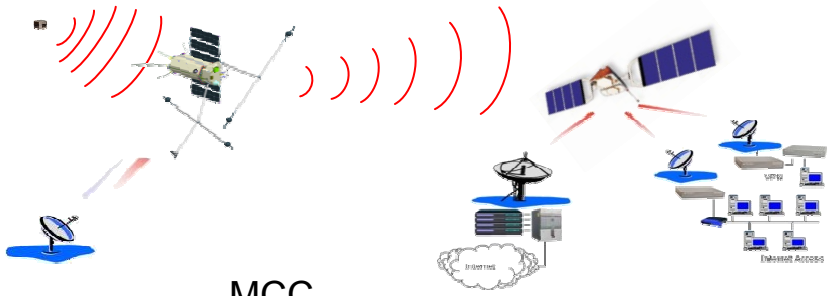
Satellite design and manufacturing, design of space constellation and operations will be carried out in partnership with **SSTL**

Airborne segment

Airborne laboratories and tethered balloons operating in seismic and volcano regions

Ground segment

Network of geophysical stations in seismic and volcano regions and the complete ground infrastructure providing operation of the system as a whole and delivery of an early warning service



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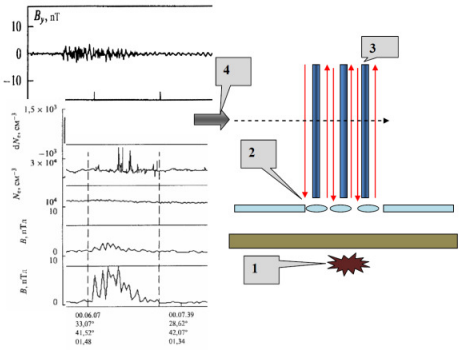
TWINSAT
Technical Outline

2. Operational satellite constellation with airborne and ground based networks for forecasting and mitigation of large-scale natural disasters

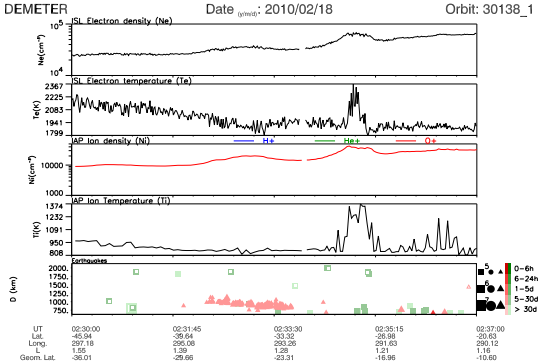
Data provided by space segment

- Disturbances of DC electric field and small-scale geomagnetic field-aligned electric currents
- Localized disturbances of thermal and supra thermal plasma parameters and ULF/ELF electromagnetic wave intensity
- Distributions of low energy electron and ion fluxes
- Altitude profiles of electron density and ion composition disturbances in the ionosphere
- Variations of ground-based VLF transmitter signals parameters observed in the ionosphere
- Bursts of VHF/UHF radio emission from the atmosphere not related to thunderstorm activity
- IR images, thermal anomalies and local intensification of outgoing long wave radiation of the atmosphere as obtained from IR (infra red) observations

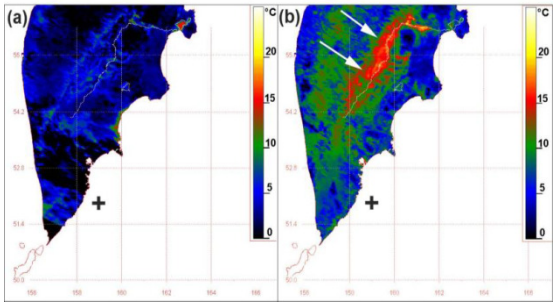
Some data samples



Chmyrev et al.



Parrot



Tronin et al.

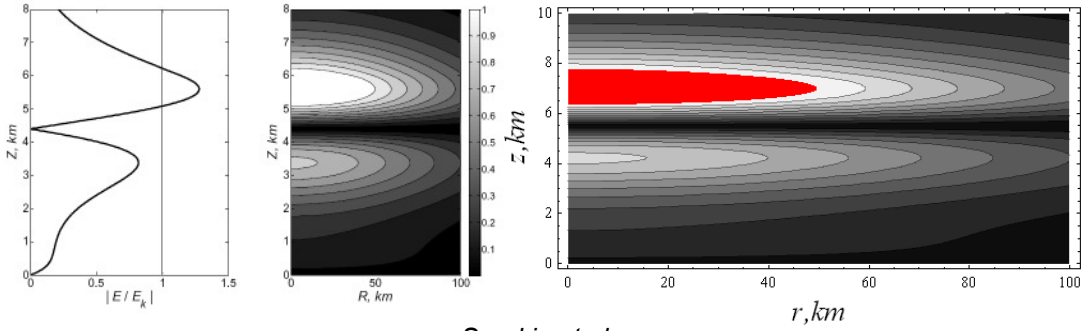
TWINSAT
Technical Outline

2. Operational satellite constellation with airborne and ground based networks for forecasting and mitigation of large-scale natural disasters

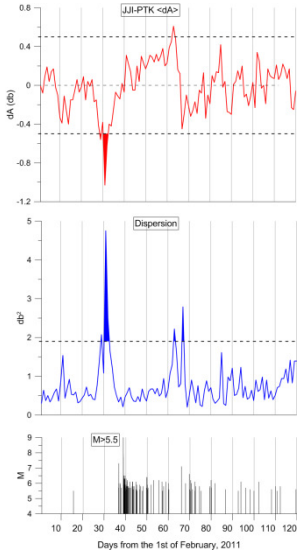
Data delivered by airborne segment

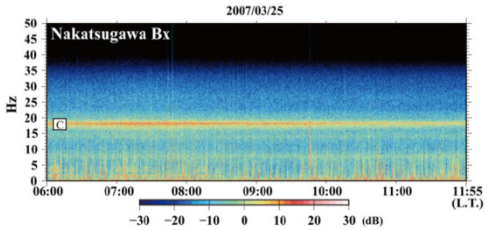
- Disturbances of chemical composition of th atmosphere
- Disturbances of concentration and spatial distribution of aerosols
- Variations of DC electric field and current i the atmosphere not related to thunderstorm
- Disturbances of natural ULF/ELF wave characteristics connected with the lower ionosphere modification
- Amplitude and phase variations of ground-based VLF and LF transmitter signals connected with the lower ionosphere modification
- Intensity of pulse VHF/UHF electromagnetic radiation and atmospheric emissions not related to thunderstorm activity
- Data on ground temperature and lightning activity

Some data samples



Sorokin et al.





Rozhnoi et al.

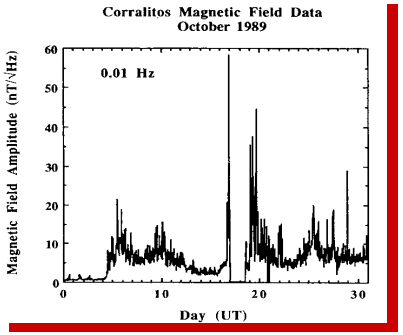
TWINSAT
Technical Outline

2. Operational satellite constellation with airborne and ground based networks for forecasting and mitigation of large-scale natural disasters

Data delivered by Ground segment

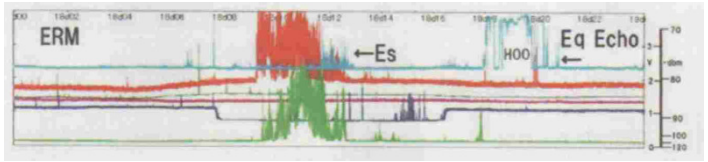
- Atmospheric gas composition
- Radon emission parameters and variations of radioactivity
- Intensity of aerosol injection
- Disturbances of DC electric field and currents
- Disturbances of spectral and wave characteristics of ULF/ELF/VHF electromagnetic emissions
- Amplitude and phase variations of ground-based VLF/LF transmitter signals
- Ionosphere disturbances and earth deformation data
- Seismic and magnetic oscillations
- Debit, temperature and chemical composition of underground waters
- Air temperature, humidity and pressure and wind velocity

Some samples of data

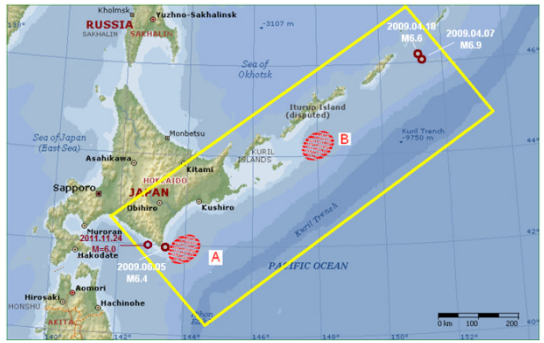


Frazer-Smith et al.

Moriya et al



Rogozhin et al.



TWINSAT
Interest for Insurance Community

Demand for the TWINSAT products is driven by enormous (exceeding billions of USD) economy losses of the countries in the seismic zones

- March 2011 earthquake and tsunami in Japan caused losses exceeding USD 100 billions for Japanese insurance community and related losses for world economy are estimated at USD 265 billions
- The Chinese government has spent about USD 150 billions to rebuild areas ravaged by the Sichuan earthquake

Interest for Insurers and Reinsurers

- TWINSAT medium-term forecast with support of ground data provides quality estimate of large magnitude earthquake risks in the timeframe ~1 year
  → helps in contracting process
- TWINSAT multi-parametric data analysis provides much more accurate and relible short-term (1 to 30 days) forecast than any of currently used methods
  → gives an additional service for various types of contracts
- Access to daily updated forecast gives the opportunity to timely inform insureds on impending catastrophic event
  → clients' awareness and potential decrease in claim amounts
- TWINSAT by-products: flood and fire imaging, data on solar activity and the health effecting geomagnetic storms, radioactive and chemical pollutants, etc.