Project of space experiment "Shadow" on ISS

New challenge and new opportunity
for Amateur Radio Community

Invitation

- **Russian Federal Space Agency (Roscosmos, the Russian analogue of NASA, ESA, etc.) and its leading research organization, Central Research Institute of Machine Building (TsNIIMash) invite VHF Amateur radio operators to take part in the space experiment "Shadow" on International Space Station.**

Organization

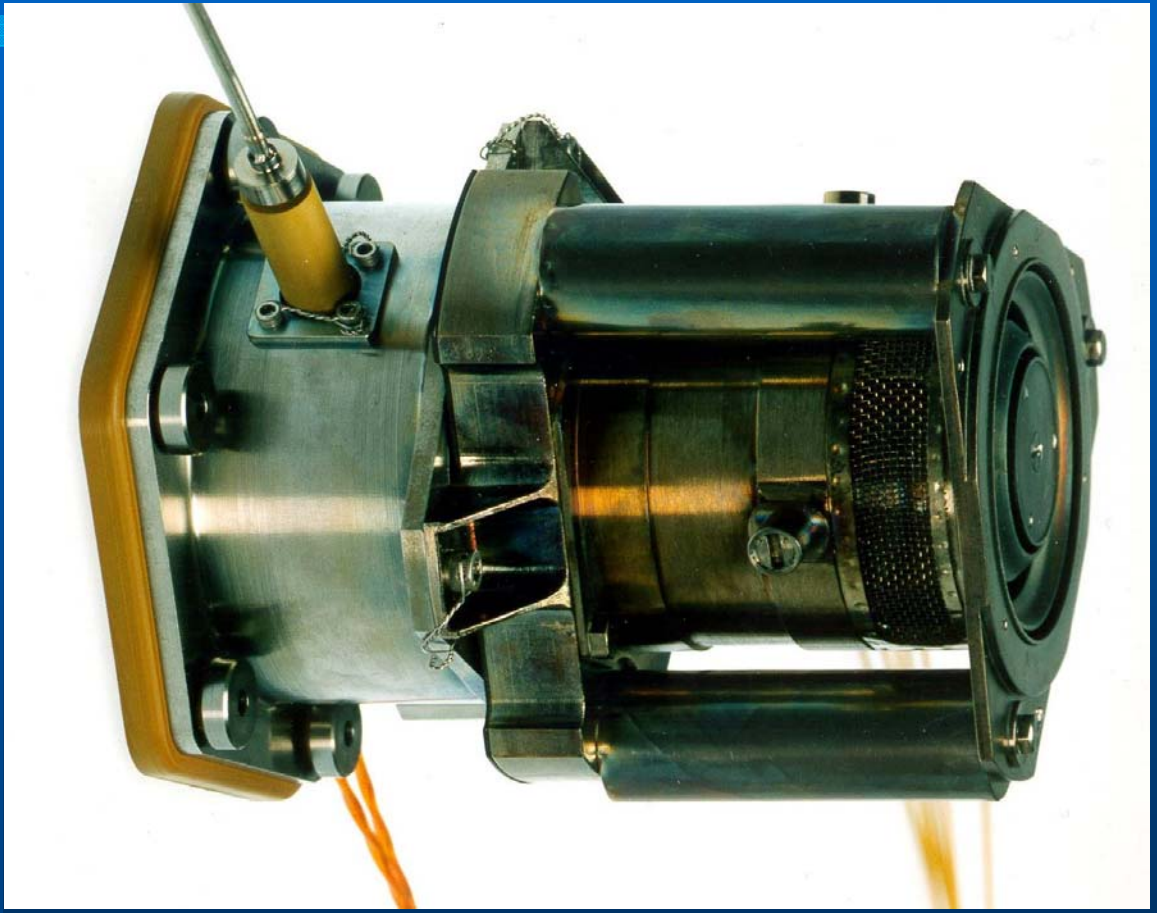
- **TsNIIMash is today involved in the design and exploratory research to substantiate a reasonable engineering policy in the development of rocket and space technology. It is involved in fundamental and applied research in aerogasdynamics, heat transfer and thermal protection, dynamics, strength and reliability of launch vehicles, spacecrafts, orbital stations and space vehicles.**

The Mission Control Center in Korolev town, Moscow region, is one of TsNIIMashs' departaments.

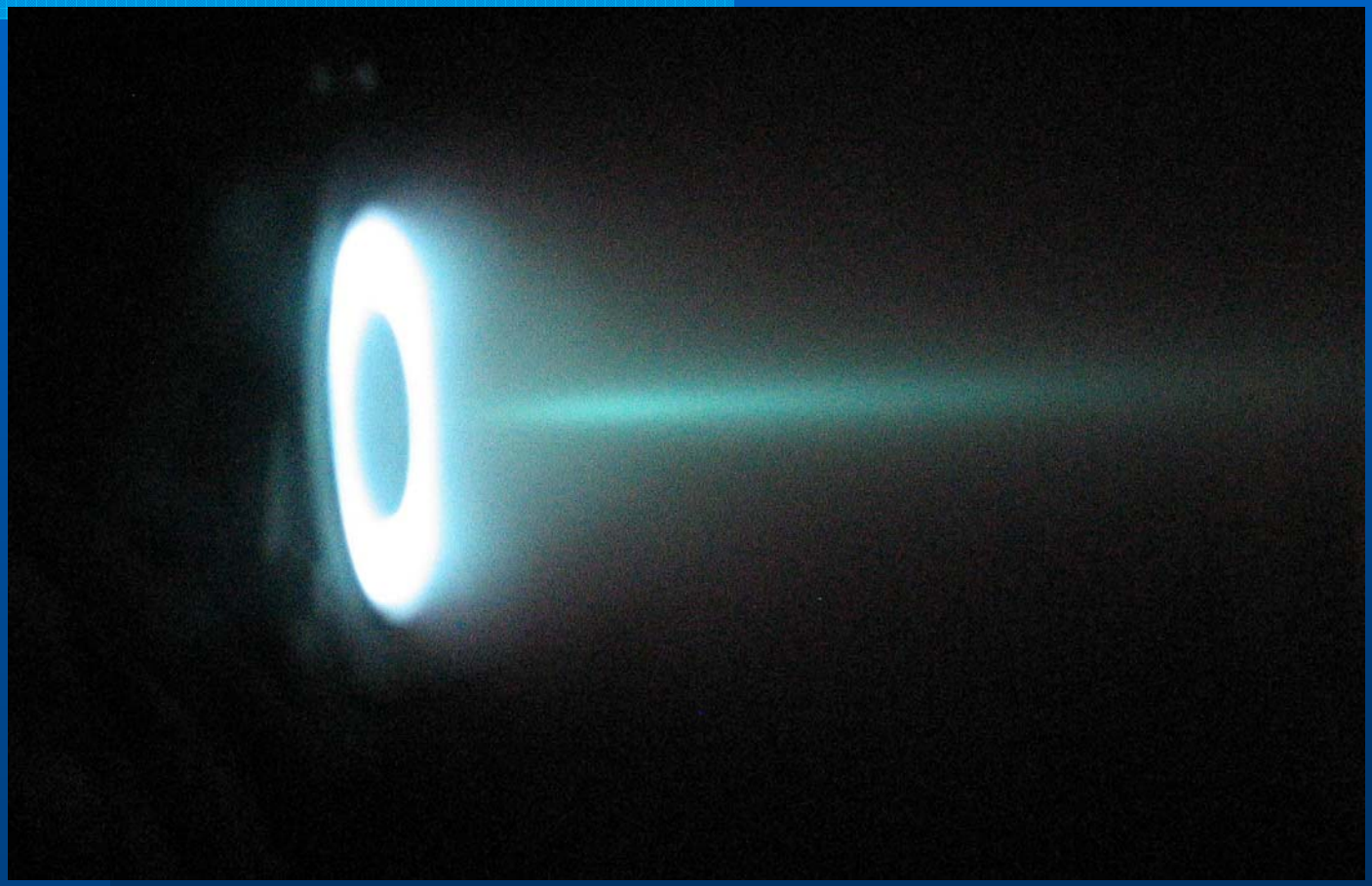
Motivation and background

- TsNIIMash's activity includes such new technology as electric propulsion. Unlike ordinary chemical propulsion systems, electric thrusters (ETs) demonstrate higher exhaust velocity, since the propellant is accelerated for propulsion by electric power. It saves propellant and reduces weight of a spacecraft, but ETs' ionized exhaust plumes can scatter radio waves and disrupt communication.
- In SpEx "Shadow" we are going to study this effect in order to overcome it in future flights of electrically propelled spacecrafts.

One of TsNIIMash made Hall electric thruster, TAL-WSF, had been successfully flight tested on American satellite STEX in 1998



This is a photo of Hall electric thruster plume in a vacuum chamber



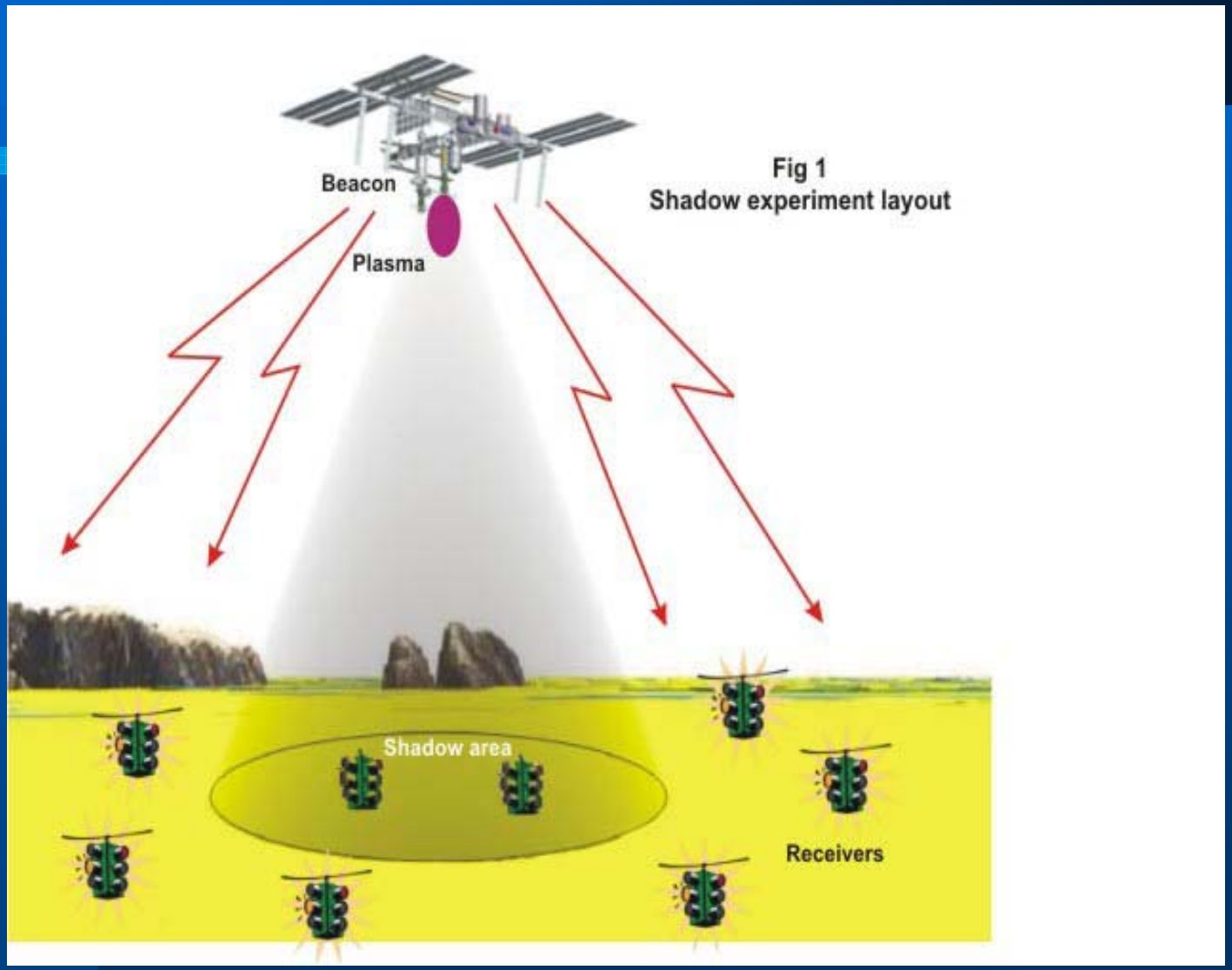
"Shadow" General condition

- The space experiment "Shadow" may be successfully performed under the condition that the number of participants will be great enough . The greater this number the more precise scientific result would be issued.

Goal

- **The objective of the work is observation of refraction/scattering effects in artificial plasmas using method of RF sounding in space experiments under different geophysical conditions.**

Lay-out


Beacon
Plasma
Fig 1
Shadow experiment layout
Shadow area
Receivers

Description

- **In the chosen region the onboard arcjet source injects a plasma plume in space and the onboard radio beacon transmits 144 or 430 MHz sounding signals with Time marks. Passed through the plasma these signals are being instantly received by an on-ground amateur VHF net-work. Due to refraction/scattering of the sounding signals in the exhaust plume, the shadow region would arise adjacent to the satellite. When the shadow boundary running after the satellite along the Earth surface reaches any on-ground receiving site the signal cut-off is to be registered.**

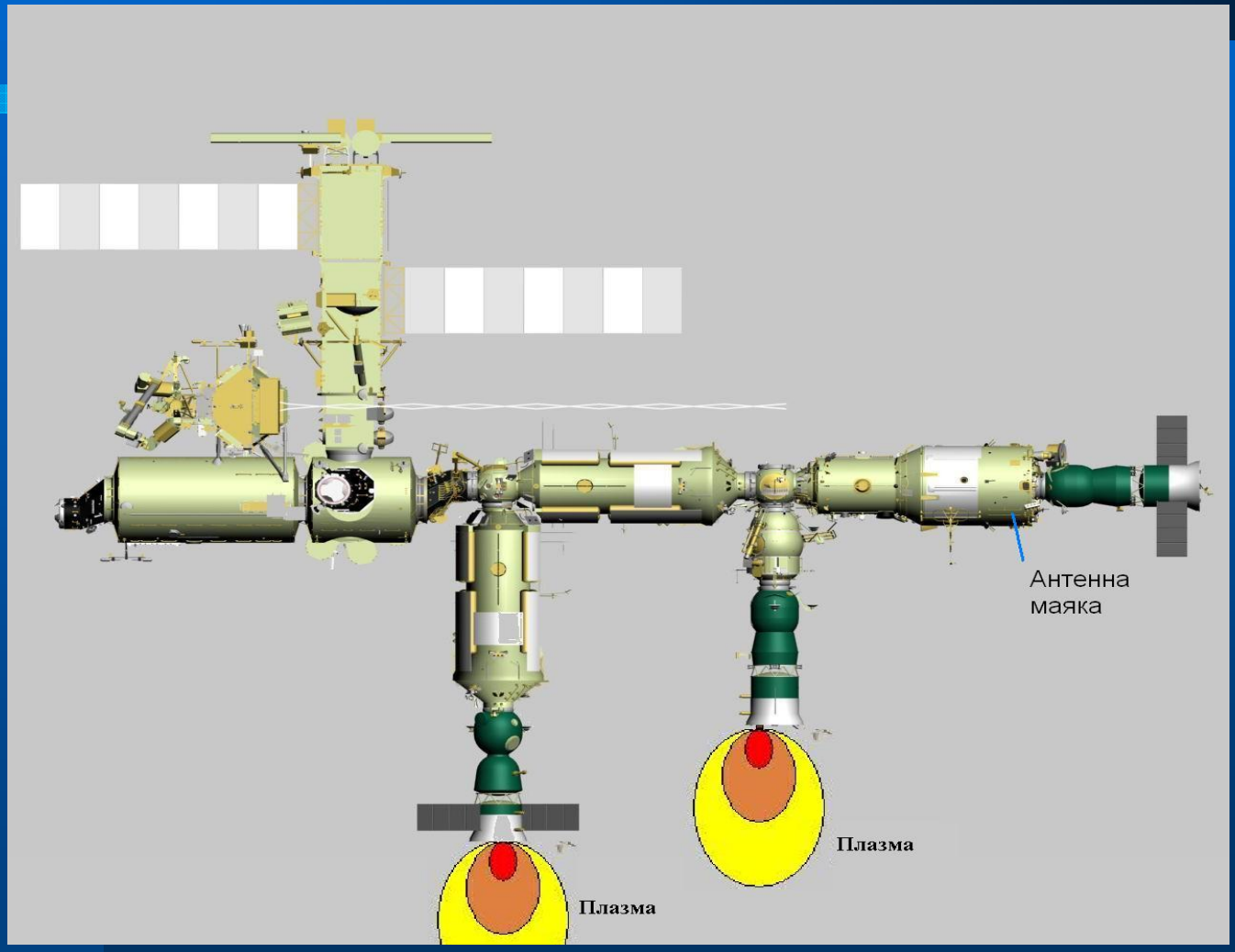
Equipment in use

The available onboard AR equipment “Sputnik” will be used for sounding of undersatellite space in 145/430 MHz band.

Cosmonaut Sergey Krikalev at the “Sputnik” site.

How it may be arranged on ISS

Two planned versions of placement of plasma source being attached to transport vehicle “Progress”



Task

- **The task of every individual participant is to register moments of signal cut-off and following signal restore using the Time marks and to address this information along with data on its geographical position to the Information Storing Center. Every operation sequence would take up to 15 min. while the satellite is passing over the given measuring field.**

Two phases of the Project

- The SpEx "Shadow" is included in the Program of experiments and researches on Russian segment of the ISS.
- The SpEx "Shadow" will be performed in two stages:
- • of "cold" (with no plasma injection) training seances and
- • of full scale "hot" experiments with plasma injection.
- What Amateur Radio frequencies will the project utilize?
- The project will utilize 144MHz and/or 430MHz band downlink. Calculation for sounding with 28 MHz predicts full black-out. However we plan to perform at least one "hot" run to check whether it is true.

Actually the SpEx "Shadow" consists of three parts:

- **Programmed plasma injection up to 25 seanses of about 15 minutes duration each.**

  This is responsibility of TsNIIMash and funding from Roscosmos.

- **Programmed translation of sounding signals by available onboard Amateur gear.**

  This is responsibility of the crew according to their flight task with technical assistance of ARISS concerning serviceability of available onboard Amateur gear.

- **Receiving and processing of sounding signals by available ground mozaics of Amateur radio receivers.**

  This is good will and personal interest of Amateur radio operators.

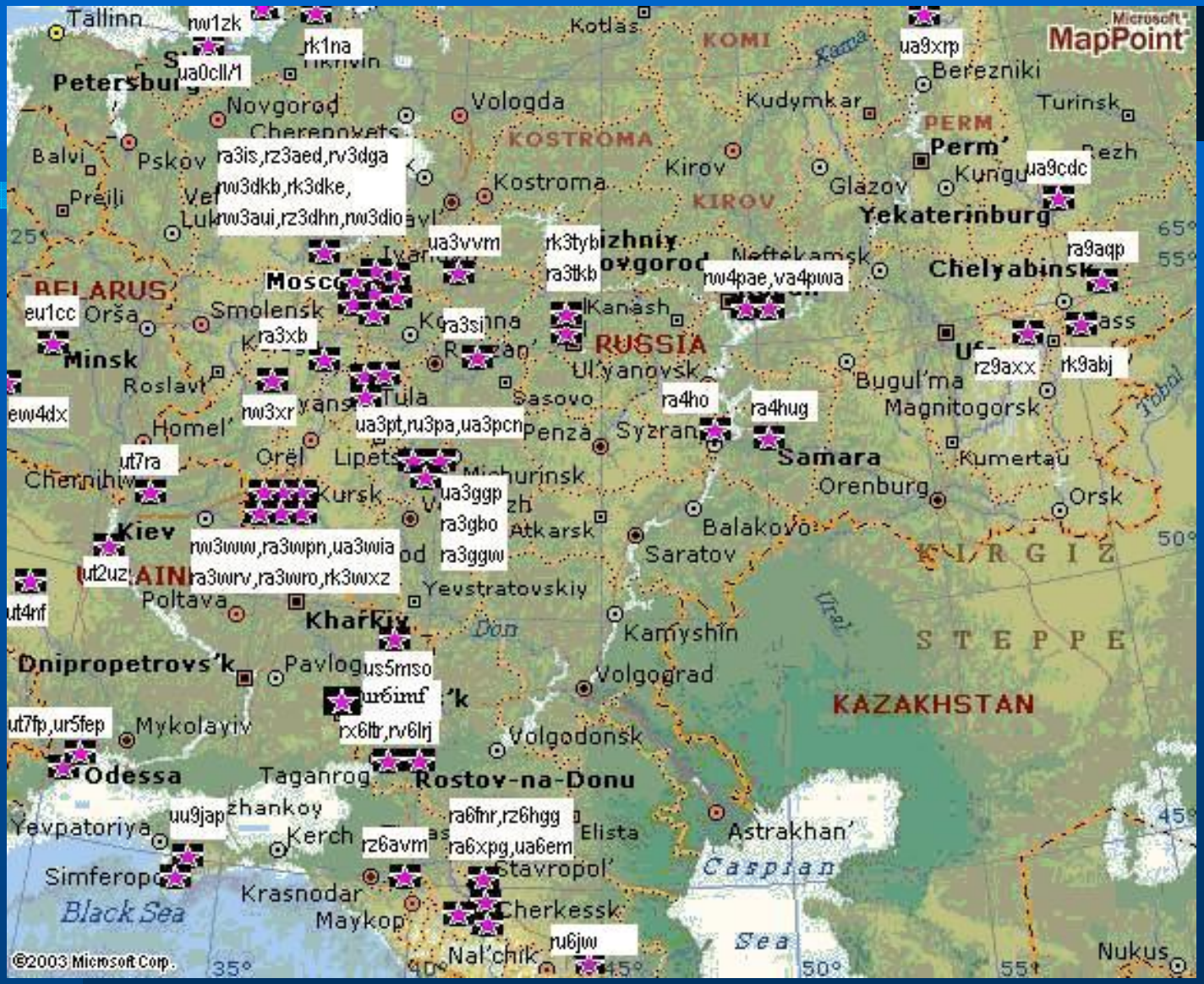
- **Processing and analysing of obtained data.**

  This is again responsibility and scientific interest of TsNIIMash.

The general issue of 2007

- The project "Shadow" has got a noticeable support from Amateur radio operators (more than 200 person in total) resulting in formation of a few measuring fields.
- Guy Roels (ON6MU, Aalst, Belgium) has developed and presented a convinient short beacon program for generation of sounding signals. It's version UISS 5.1 is certificated for onboard use.
- In October 2006 and December 2007 auxiliary sessions of "cold" experiments in a digipeater mode (legend "Shadow - beacon") have been performed and demonstrated the principal features of the sounding methodology.

East-European measuring field



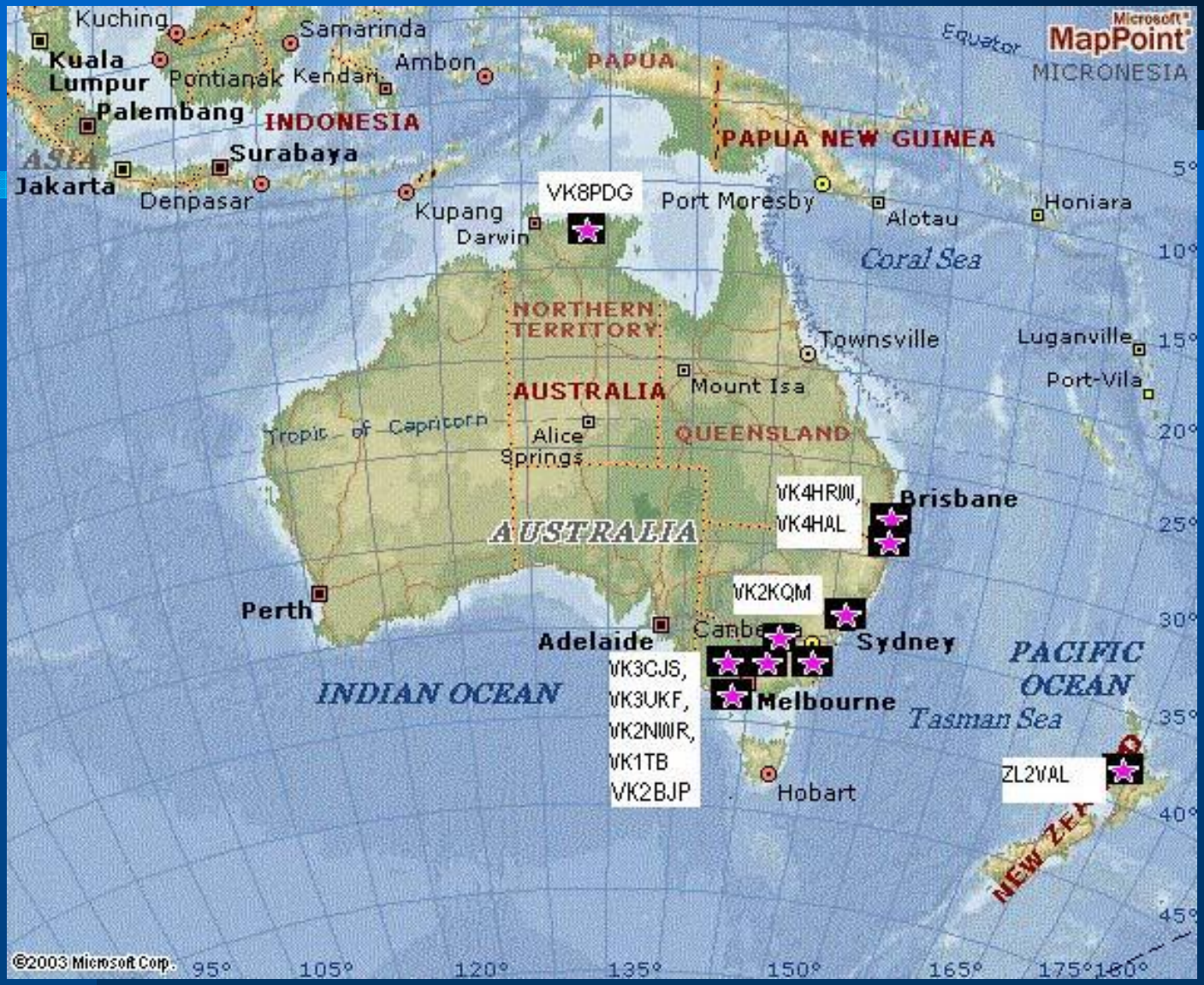
West-European measuring field

North-American measuring field

South-American measuring field

Asian measuring field

Australian measuring field



Shadow-2008

- Last spring the onboard AR equipment “Sputnik” was added with PC already loaded with certificated UISS 5.1 allowing to perform straight sounding from orbit (no digipeater mode).
  - “Cold” phase of the project, SpEx "Shadow - beacon“, is included in the operating plan of 18-th expedition on ISS and is expected to be completed in the end of 2008.
  - The purpose the "cold" stage is to specify all procedures, to check readiness of the receiving network and to collect reference data for the "hot" stage.

Problems (except funding, papers, certification, approvals etc.)

- Number of participants; we need at least a hundred of ground operators on each measuring field;
- Possible inaccuracy in measurements due to unequal sensitivity of ground net-work;
- How to involve new volutears who have only radio with no computer and Internet (it may be useful for, say, deep Russia);
- And many others currently invisible.

What else

- The same technology can be also applied in a space experiment on sounding of not artificially injected plasma, but of the natural ionospheric plasma in HF frequency band (14 and 28 MHz). It is expected, that due to dispersion of sounding radiation in ionosphere, an "irradiated" spot should appear on the Earth surface, and determination of boundaries of this "irradiated" spot is the science purpose of the space experiment (legend "Spot"), which can be carried out not on the ISS but on a proper amateur satellite. This idea is currently under development.

Expected results

- The scientific results of the SpEx "Shadow" will help designers of future electrically propelled spacecrafts to minimize the hazard of communication disruption by ETs' plasma plumes.
- Also realization of the space experiment "Shadow" will give an unique example and experience in involving of intellectual and technical potential of International Aamateur radio community in perspective scientific projects.
- It seems that the greatest world hobby does not properly understand its own strength and capability. There is a modest hope that the "Shadow" project will turn the Amateur Radio Community to see it better.

Project of space experiment "Shadow" on ISS

New challenge and new opportunity for Amateur Radio Community

Let us do this job together!

Russian Space Agency and Russian cosmonautic federation are going to award every participant of the space experiment "Shadow" with special diploma.

Appendix A

“Cold" experiments in a digipeater mode

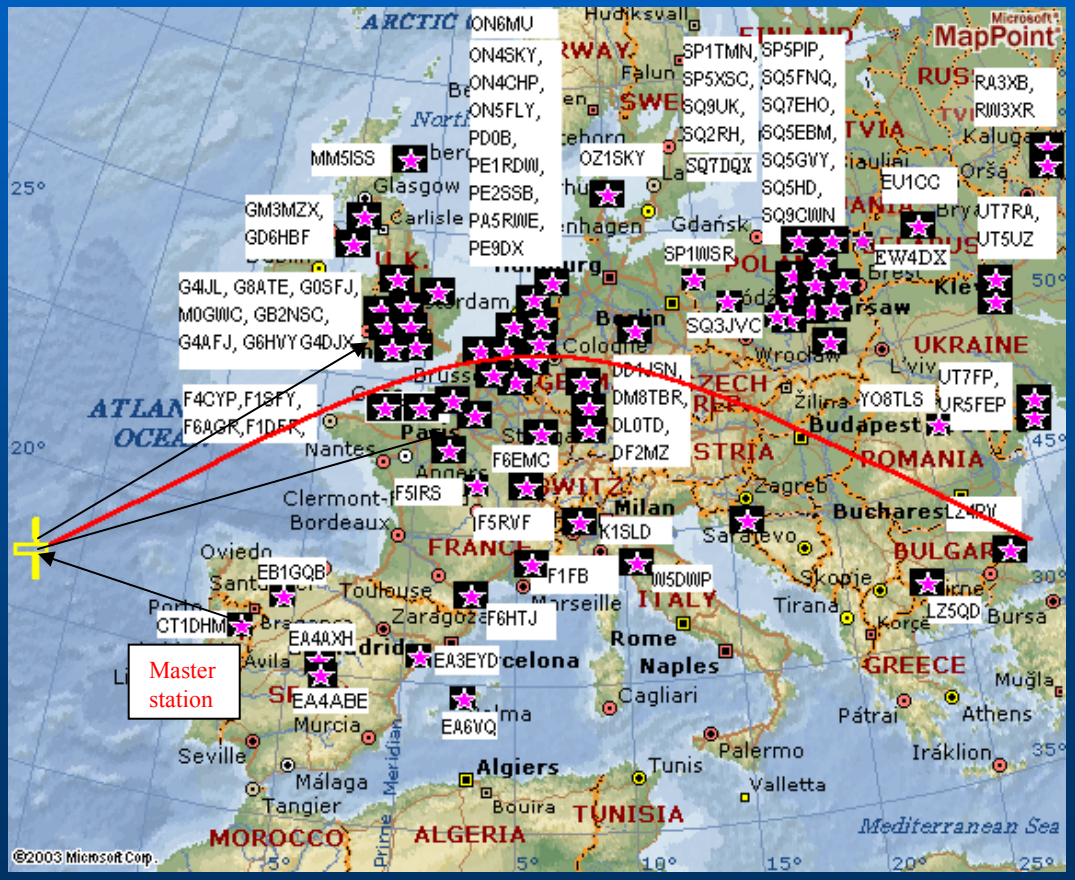
- In October 2006 and December 2007 auxiliary sessions of "cold" experiments in a digipeater mode (legend "Shadow - beacon") have been performed and demonstrated the principal features of the sounding methodology.

Sounding signal from ground master

- In this auxiliary cold session as ISS approaches a given measuring field, one of western stations of this field takes up a function of a master station and sends to the ISS's digi a sounding signal (marks of time). The remaining stations of the measuring field start registration of the digipeated signal as they occur to be within of ISS footprint. Further the function of a master station is taken up by one of eastern stations.
- Some field stations (in the center of the measuring field) may pick up signals of the western and the eastern master stations both. Some will receive no useful signals. It is also an important observation.

Lay-out

only for illustration with no real concern to call-signs



General results of cold session in 2007

- **Sessions of SpEx "Shadow - beacon" on the European measuring field have been conducted between 2007 November 26 and 2007 December 2.**
- **Short beacon program version UISS 5.1 was successfully used for generation of sounding signals.**
- **45 reports in total have been presented from 23 ground receiving sites to the Information Storing Center (shadow@tsniimash.ru).**

Dislocation of receiving sites

General conclusions from data processing

- Short beacon program version UISS 5.1 ticks properly with time discrete step 2-3 s.
- Unequal sensitivity of ground net-work really plays negative role predominately in dependence on quality and elevation of antenna.
- “Cold" experiments in a digipeater mode does not allow to check whether radio silence may be provided as it is expected under the AX25 Protocol of radio communication in the conditions of generation of a short beacon.
- Autumnal experiments with straight sounding from orbit should be more informative, additionally it is recommended to perform pulse mode of sounding: say, 40 sec. - generation, 20 sec – pause.

Appendix B

What support is expected from ARISS

- To use ARISS capability for informing of ham community about the project and in announcement on its time-frame.
- To use ARISS experience in school work. The space experiment "Shadow" also may bring an important social result attracting public attention especially students and pupils to advanced technology, astronautics, electric propulsion, amateur packet radio and Internet.
- Personal participation as a field operators.