MICRO-SATELLITES - AREAS OF UTILIZATION AND DESIGN PRINCIPLES

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Abstract

Among 6-7 problems of modern astronautical designing there is one which is not evident but very actual. The paper shows the place of Small Satellite Systems (SSS) among modern missions. They are especially usefull in experimental and modeling researches which are based on new technical fenomena. They will have special role in serving of manned orbital stations and lagre sattelites.

For SSS is tipical not only small size, mass and consumption of spacecraft. They have their own logic of designing and building, their own role in astronautical missions.

1. MAK-Series of small satellites MAK-1,...10 of Research Institute of Applied Mechanics and Electrodynamics (Moscow) is able to represent such a systems (Table 1,2).

MICRO-SATELLITES - small AES (M-AES) of mass 10-50kg with onboard consumption 0.25/20W (in duty and peak regimes). They are ordered for precessional investigations of medium, Earth monitoring, joint work with large base spacecrafts, in 'cluster' polisystems, for real simulation of new mechanical, energetical, informational space technologies. Series of satellites MAK-1...10 of Research Institute of Applied Mechanics and Electrodynamics of Moscow Aviation Institute may stand duty as an example of M-AES system (table 1,2).

DESIGN OF M-AES is defining by limits severity, relative narrowness of functional tasks and limited resource. Dominantional part of diagnostic equipment defines non-tightness design of device module. Low onboard consumptions requires increased range in the area of negative temperatures (-20...0°C).

BALLISTIC AND ENERGETIC of trajectory operations are connected with passing M-AES insertion, usage of "packet" schemes and small launch rockets. Movement is investigating in coordinates of tracking object or reduces to building of spatial polisystems. Low characteristic speed of operations V_{char}=10-50m/s and corrections periodicity suppose usage of systems with working body keeping in the case of non-typical mono-fuels decomposition. Energy supply is carring out by means of solar and chemical batteries in the case of nontypical voltage of onboard net (15V).

SYSTEM OF ORIENTATION may be absent, when scientific measurements connects with orientation of apparatus relating to fixed vector of magnetic field, coordinates of Earth, Sun, object of investigations. For apparatus orientation external factors are using (atmosphere, gravitation and magnetic fields) with dynamic dampering and transducers platform correction.

INFORMATIONAL SYSTEM with minimum filtration and information onboard packing uses relatively powerful multichannel transmitters (4W) with high frequency of polling (3500Hz). Information discharge is duplicating many times.

PRACTICLE UTILIZATION of M-AES series, passed standard cycle of tests in "Energiya" Enterprise and laboratories of MAI, was started in 1991 by test of satellite MAK-1 insertion through "MIR" orbital station air lock and would be continued in the end of 1992 by launching of AES MAK-2 from "MIR" station and AES MAK-4 from spacecraft of "KOSMOS" series.

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Table 1.

"MAK-1....-10" - SERIES

Satellite type	Diagnostic			Aerodynamic		Tether		Orbital station service		Ecological
Characteristics	MAK-1	MAK-2	MAK-3	MAK-4	MAK-5	MAK-6	MAK-7	MAK-8	MAK-9	MAK-10
Mass, kg	22	20	25	92	27	30	46	36	37	225
Overall dimensions -in transportation state	480x330 x380	517x320x320		o 330	o 330	o 320 x400	o 320 x525	o 320x525		o 1100x2000
-in operation state	480x 3630x 3630	517x3660x3660		o 330	o 1000	tether leng. 1+1	leng. of: tether 20km, cable 1km	o 320x1000		boom length 20m
Informativity of telemetrical system kBite/c	25.6 (16-64 channels, frequency of polling up to 3500Hz)							100	100	200
Power consumption, W -peak	5	7.5	15	6.6	6.6	10	20	10	10	80
-duty	0.25	0.75	0.75	0.3	0.3	0.5	0.5	0.6	0.5	30

Table 2

TECHNICAL CHARACTERISTICS OF "MAK" SERIES SATELLITES.

Satellite type	Diagnostic			Aerodynamic		Tether		Orbital station service		Ecological
Characteristics	MAK-1	MAK-2	MAK-3	MAK-4	MAK-5	MAK-6	MAK-7	MAK-8	MAK-9	MAK-10
Purpose	Investigations of high atmosphere, space plasma diagnostics, active experiments carring out			Investigations of high atmosphere density variations		Investigations of tether systems characteristics, investigations of electromagnetic interactions		Tracking and service of orbital station, probeing of near-the-object medium, manoeuvre with Vchar=10-50m/s		Ecological monitoring of high atmosphere and ionosphere carring out
Scientific equipment composition	Mass-spectrometer, magnetometer, radio beacon	Spectr. probe, magnetometer	Mass-spectrometer, spectr. probe, magnetometer	Microaccelerometer, magnetometer		Probe equipment, current in tether meter, impedancemeter, hollow cathodes, accelerometer and magnetometer		Microaccelerometer, videocamera, magnetometer, equipment for study of physical fields of orbital stations		Videocamera, mass-spectrometer, spect. probe, magnetometer
Typical orbit	Circular H=380-420km			Circular H=250km		Circular H=380-420km		Circular H=380-420km		Circular H=700km Elliptical H=400km H=2000km
Orientation	Non-oriented Measurements coordination by vector magnetometer			Aerodynamic (by the velocity vector, accuracy 5-7°)		Gravitation (by local vertical, accuracy 2-3°) Gravitation-dynamic (accuracy 0.1°		Aerodynamic (by velocity vector, accuracy 5-7°)		Gravitation-dynamic (by local vertical, accuracy 5')

2. Small-size diagnostic satellites "MAK-1,-2-3"

Small satellites have great potential in investigation of nearearth space, such as:

- -separate exploration of spatial and temporal variations of atmosphere, ionosphere and magnetosphere parameters;
- -investigation of fine structures of localized formations in nearearth space, such as upper atmospheric cyclones, main ionospheric gap and cusp area, plasmapause, magnetopause, etc.;
- -investigation of local anddistant nearearth space effects during active experiments;
- -study of peculiarities of various frequency ranges radiowaves propagation in ionospheric and magnetospheric plasma;
- -control of nearearth environment by multipositional measuring means.

The satellites are inserted into orbit together with "mother" spacecrafts or throuth the "lock chamber of "Mir" station".

Main advantage of autonomous subsatellites is a possibility of conducting "pure" measurements of parameters of upper atmosphere and ionosphere, electric and magnetic fields and electromagnetic emissions because of great disturbances of large-scale spacecrafts (especially such as orbital stations) environment.

The science equipment of "MAK-1" satellite comprises:

- -mass spectrometer MX6407, designed for neutral and ion content analysis;
- -radiobeacon for study of short waves propagation from space to Earth.

Pressurized Ni-Cd accumulators are used as a power source on board the satellite.

"MAK-2" satellite is designed for quasistable electric fields intensity measurements, current-voltage probes characteristics and ionospheric plasma inpedance determination.

Satellite service equipment comprises:

- -three-component magnetometer for determining subsatellite orientation relative to Earth magnetic field;
- -system for measurement of subsatellite elements and units temperature;
- -telemetry system with time-pulse signals modulation and time division of channels;
- -program-controlled timing device providing the satellite operation in strict cyclogram.

On board the "MAK-2" satellite power supply system comprising Si-solar batteries mounted at the edges of spacecraft body and buffer batteries is used.

"MAK-3" satellite combines science equipment of two previous models. It is equipped with deployable twingsided solar batteries of increased capacity and control system reprogrammable for concrete investigation task.

Mass	
total	25 kg,
scientific equipment	8-12 kg.
Useful volume	6-10 l.
On-board power	5-15 Wt.
Operating life	from 3 hours up to 30 days.

3. Small-size airdynamic satellite "MAK-A" ("MAK-4,-5")

Satellite is designed for investigation of parameters variation of earth's atmosphere, on altitudes 300-150, aimed at:

-defining more precisely earth's atmosphere model (about 10-15% on dencity, gas composition, absorbing ultra-violet part of specter of solar radiation);

-studing the atmosphere fluctuations as secondary displacement of the activity in "Earth-Sun-Moon" system;

-investigating local processes of earth's crust, world ocean, ecological phenomena;

-developing and verifying the big claster system for monitoring upper atmosphere layers.

Claster system of the SAS "MAK-A" ensures, altitude echeloned, covering polar, equatorial and predetermined anomalies regions upper atmosphere layers, with predetermined frequency and periods due to individual and group launching of the SAS and satellite airdynamic maneuvering.

Storage information system allow to analyse the atmosphere model parameter deviation at settling time and the coordination base, to fix anomalyes of armosphere's geometry, local flows in the global scale.

Full-scale system includs 16-24 spacecrafts with the common information bank, united center for processing satellite's information and observations from the Earth.

SAS "MAK-A" is launched, to the altitude 250-300 km, as balancing load, together with the main spacecraft. SAS launch is planned to be in the 1992 year. After jettisoning from main spacecraft, SAS "MAK-A" performs autonomous flight. First

flight phase (1-5 days) includes decreasing rotation of angle velocity due to magnet-gisteresis desphering. Second flight phase (1-2 days) realizes unfolding inflatable airdynamic stabilizer (1000 mm in dia). Thhird flight phase performs unfolding "stabiliser-tether-SAS" tethered system. Tether length is approximately 1 km. Before reentry in dense atmosphere layers, SAS existence time equales approximately 6 days.

SAS has spheric shape and includes the following systems:

-scientific module having 2 precision three-axis accelerometer with sensitivity about 10(-4), 10(-6)g, magnetometer, sensor of surface temperature;

-flight control module (dogital computer. block processing of the scientific information);

-mechanical module for airdynamic orientation of programming deceleration with using inflatable stabilizer and oscillation dempher;

-service systems module (telemetry, powersupply, thermocontrol).

Technical characteristics:

SAS mass	40 kg
Diameter of SAS sphere body	330 mm
SAS time existence before reentry, about	40 days
SAS active lifetime	3-40 days
Airdynamic orientation accuracy	8-10 deg
Orientation definition accuracy	3 deg
Angle of bank velocity	2 deg/sec
Density definition accuracy	10%
Frequency communication links	4-12 p/day
Telemetry channels number	32
Constant inboard powersupply	0,05 wt
Maximal inboard powersupply	6 wt
Calculated launch overloads n(x,y,z)	-10,+10

4. Small tether system (MAK-6,-7).

1. Base conceptions of the system:

binary mechanically coupled system of high length, inexpendable system of orientation, manoeuvring, interception, transportation in the base system environment;

-electromagnetodynamic tether system (ETS) in the modes of plasma fields, engine, generator, ULF antenna diagnostics;

-development of autonomous manoeuvring space vehicle- satellite of orbital station for refinement of their interaction (informational, energetic, mechanical). development of laser and UHF channels at a given distance, use of cable-light-conductor for information and energy transfer.

Experimental system solves the following tasks:

1)Investigations of modes of a TS dynamic deployment with positive tether tension at a distance of 1-20km. TC libration control at different elongation of a couple, deployment in fast (due to initial pulse) and slow (due to gravitation force) modes.

2)Insertion of a coupled module into the given space point in orbital system coordinates in the case of low of tether break being refined (tether interception).

3)Tethered bodies orbit parameters change due to their decouplement.

4)Measurement of potential at the ends of tether- cable and of current in the cable at operating one or two hollow cathodes and at their switching-off and at charges inductance at the tethered bodies frames in 'tether-generator' mode.

5)ULF radiations generation by means of a current switch in the tether (circuit). Measurement of ULF antenna impedance.

6)Measurement of plasma fields parameters in the base spacecraft environments (at active influences).

7)Investigations of possibilities of tether-light-conductor use for information and energy transfer.

Peculiarities of the experiment are in the utilization in one couple of tether-cable (1km) and tether-filament (up to 20km); electrodynamic experiments carrying out on the whole length of the couple deployment and in deployed state. System is used in a mechanical couple of generator, engine, antenna and light-conductor.

Variants (stages) of the experiment:
"MAK-6" autonomous module. It is launched through the "Mir" orbital station air lock.

Main characteristics:

Mass, kg	38
Overall dimensions, mm	320x480
Length, km	
-tether-filament	1+1
Power consumption, W h	112
Experiment duration, days	7

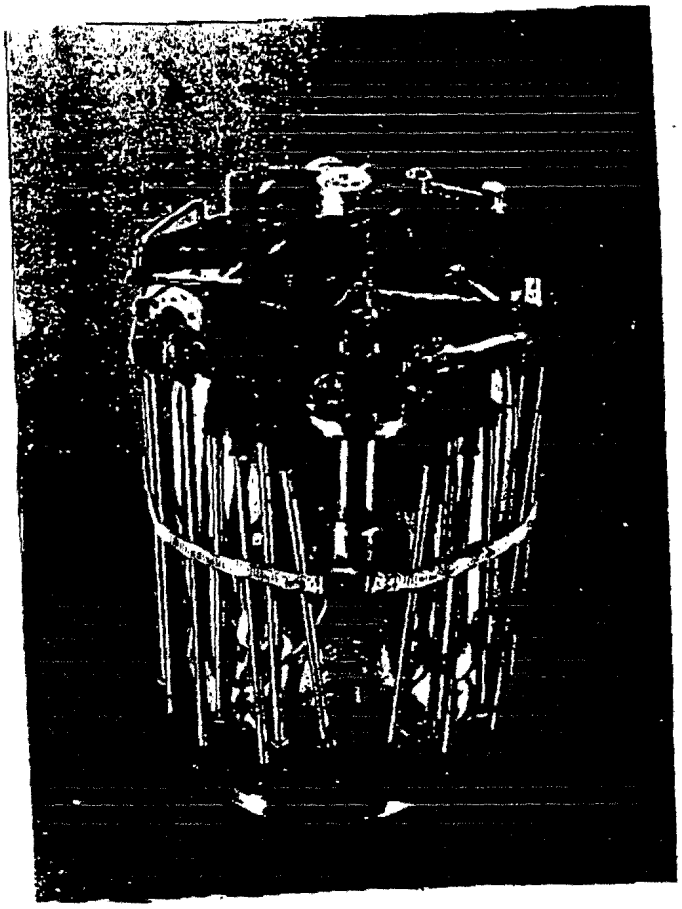
"MAK-7" - tethered module. "Progress" transport spacecraft, orbital stage of space carrier or "Buran" transport spacecraft ("Space-Shuttle") might be used as a base spacecraft.

Main characteristics:	
Mass, kg	50
Overall dimensions, mm	320x525
Length, km	
-tether-cable	1
-tether-filament	20
Power consumption, W h	112
Experiment duration, days	7

Distinctive features of technical solutions of "MAK"- series systems configuration and construction are shown in the tables 3-7.

"MAK-1,...-10" series is a bright illustration of one of the directions of airspace engineering development- research and education modeling. Solving general problems of airspace engineering at ordinary and simple enough technical base and using cheap launches it is possible to solve problems of new generation of space specialists education besides difficult tasks of technique modernization.

Table 3



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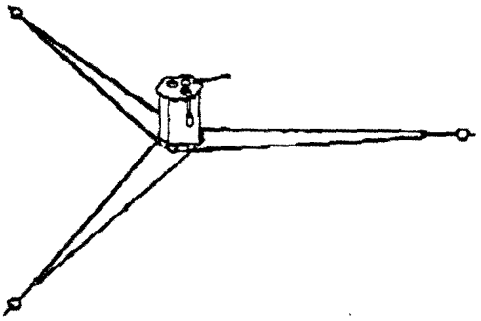
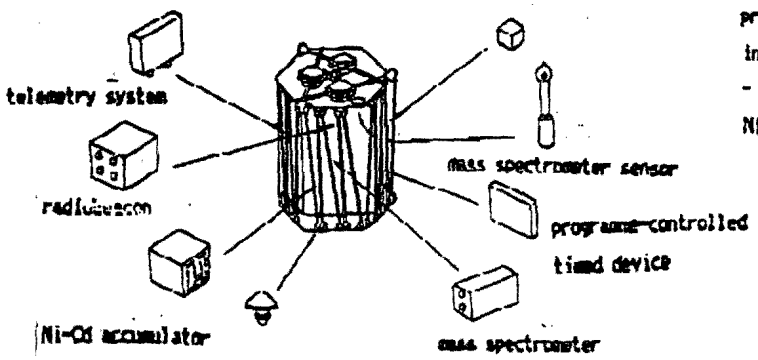
SMALL-SIZED SATELLITES OF "MAK" SERIES



MAK-1 is designed for 'pure' measurements of parameters of upper atmosphere and ionosphere, neutral and ion content analysis, study of short waves propagation from space to Earth.
Scientific equipment: mass spectrometer, radiobeacon.
Satellite service equipment comprises:
- three-component magnetometer for determination of subsatellite orientation relative to Earth magnetic field;
- system for measurement of subsatellite elements and units temperature;
- telemetry system with time-pulse signals modulation and time division of channels;
- programme controlled timing device providing the subsatellite operation in strict cyclogram;
- power supply system (solar batteries and Ni-Cd accumulators are used).



TECHNICAL CHARACTERISTICS	
Vehicle mass, kg	22
Overall dimension, mm	480x200
Power of the equipment, w (duty/peak)	0.25/5
Operating lifetime, days	30

Table 4

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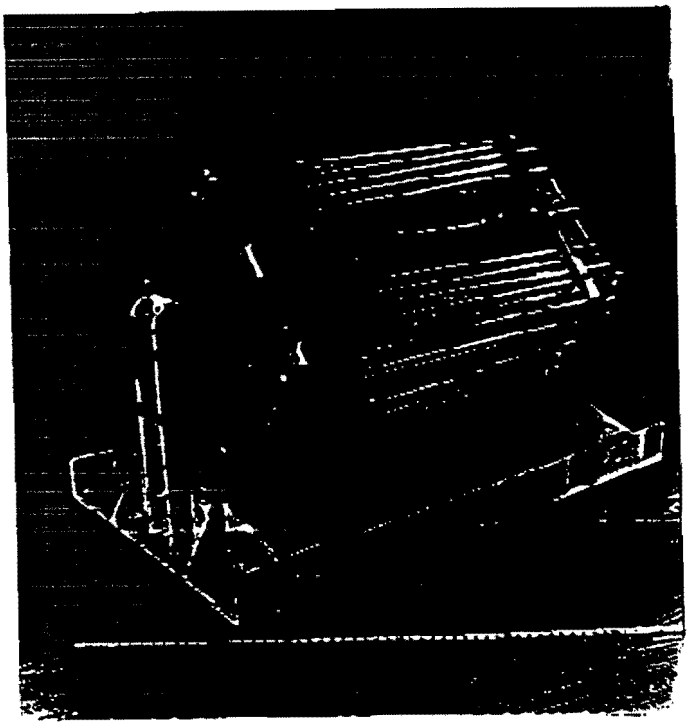
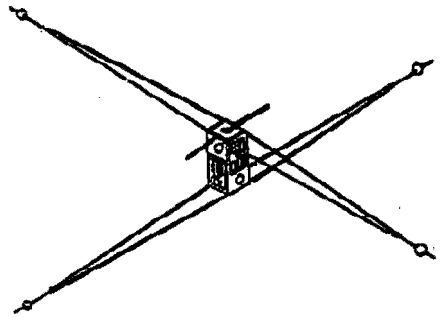
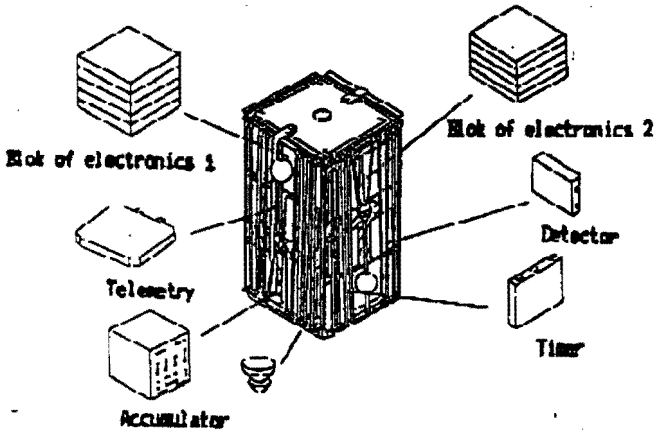


SMALL-SIZED SATELLITES OF "MAK" SERIES





MAK-2 is designed for the investigation of magnetic, electric and plasma fields of upper atmosphere and of artificial fields. Scientific equipment: "Spectr-Zond" device. Satellite MAK-2 is nonpressurized, might be launched through the air lock of an orbital station or injected together with other space objects.

technical characteristics

Vehicle mass, kg	20.5
Overall dimensions, mm	518x320
Power of the equipment, W (duty/peak)	1/10
Operating lifetime, days	30

Table 5

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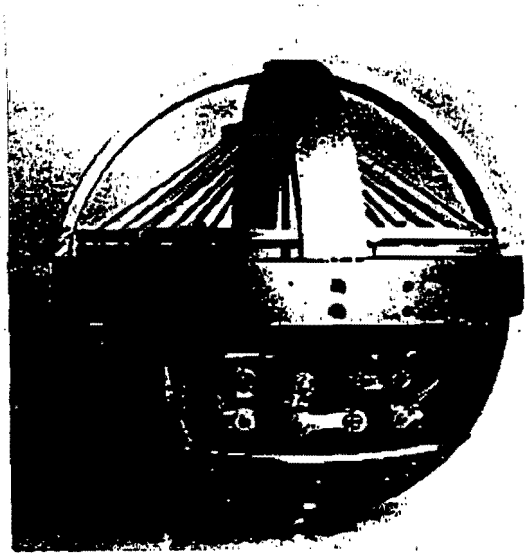
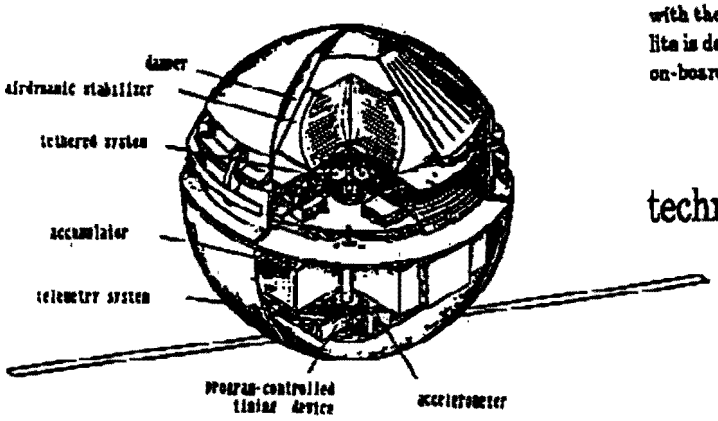


SMALL-SIZED SATELLITES OF "MAK" SERIES

MAK45 is designed for investigations of variations the Earth's atmosphere parameters, movement dynamics of AES with aerodynamic stabilisation and magnetohysteretic damping, processes of a free-molecular flow interaction with the spacecraft surface. Scientific equipment: microaccelerometer of AKC-"II" type. Satellite of MAK-A1 is injected into the orbit together with the main vehicle. Orientation of satellite is determined by a magnetometer, mounted on-board the AES.



technical characteristics

Vehicle mass, kg	30
Diamrter, mm	330
Period of active operation, days	10
Proof load factor during the injection, units	10

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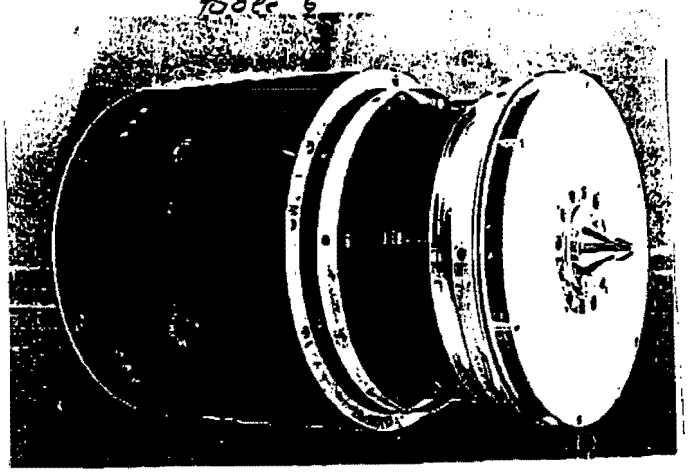
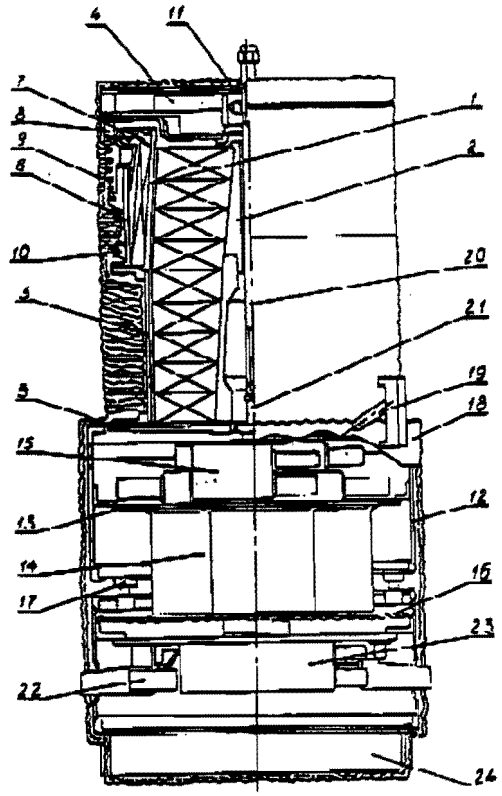
Table 6



SMALL-SIZED SATELLITES OF "MAK" SERIES



1 - external coil
2 - internal coil
3 - insert
4 - remote unit
5 - strong plate
6 - support ring
7 - tether
8 - string attachment bracket
9 - limiting cover
10- heat bridges
11- hole for tether
12- shell
13- device plate
14- chemical battery
15- service equipment
16- shield-vacuum instation
17- heat bridge between scientific and service equipment
18- shield-vacuum instation
19- directing sledges
20- lock rod
21- lock
22- hollow cathode
23- hollow cathode power supply and control system
24- plasma parameters meter

MAK -T subsatellite is a vehicle with tethered system which provides its deployment along local normal due to gravitation field gradient and autonomous probing of free space or environment of main spacecraft with which it is mechanically connected.

The overall objectives of the experiment are to:

- demonstrate the successfull operation of a tethered satellite and verify the controlled deployment.
- perform the initial electrodynamic science investigation quantifying the space plasma in the presence of a controlled electric current conducted through the tether.

The satellite is connected with main spacecraft by an insulated, conducting tether (1 km) and non-conduction tether (20 km).

Control of the satellite is accomplished by measuring various parameters (tether length, tension, etc).

Technical characteristics:

total mass, kg	45
scientific payload mass, kg	7
overall dimension, mm	525x720
length of tether, m	
- conducting tether	1
- non-conducting tether	20
power of the equipment, W (duty/peak)	0.5/20

Table 7

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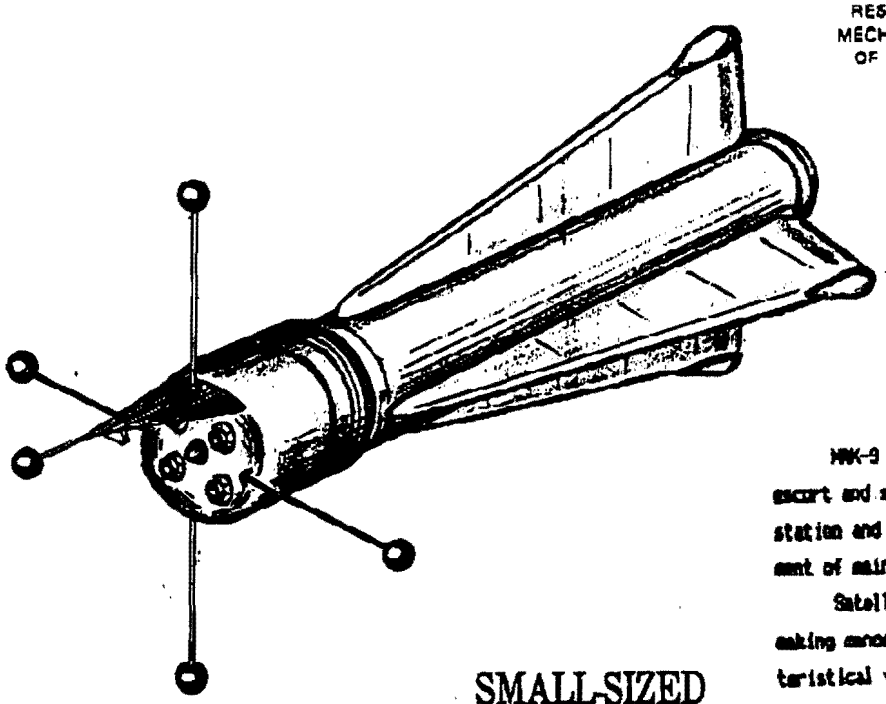

SMALL-SIZED SATELLITES OF "MAK" SERIES

1. Mirror of control system
2. Devices
3. Fixing to air lock
4. Damper
5. Board lights
6. Radiator
7. High-pressure balloon
8. Engine
9. Control engines
10. Stabilizer
11. Inflated balloon
12. Light
13. Infra-red camera
14. TV cameras
15. Antenna
16. System of day visual orientation

I. Apparatus in operative position
II. Apparatus in carrier position

MAK-9 is designed for the escort and service of orbital station and probing of environment of main spacecraft.

Satellite of MAK-9 type is making manoeuvre with the characteristical velosity V=10-50m/sec.

Scientific equipment : micro-accelerometr, videocamera, magnetometr, devices for the investigation of physical fields of orbital station.

Technical characteristics:

Vehicle mass, kg	37
Overall dimension, mm	Ø 320x1000
Power of the equipment, w (duty/peak)	0.5/10
Operating lifetime, days	30