AIST PROJECT: SCIENTIFIC AND TECHNOLOGICAL FOUNDATIONS

M.S.CHUBEY, I.I.KANAYEV, V.V.MAKAROV, V.N.YERSHOV, A.E.IL'IN,
Pulkovo Observatory
196140 Saint Petersburg, Russia

V.I.MOKLYAK, P.A.SHAKLEIN, S.M.GOLOVANOV, V.A.ZINKOV,
V.E.CHEBOTAREV, V.N.ARBUZOV, E.A.ASHURKOV, V.A.BARTENEV, G.A.TITOV,
YU.L.BULYNIN, O.V.ZAGAR, V.A.MALYSHEV, A.N.NIKITENKO, YU.D.SERGEEV,
Consortium of Applied Mechanics
660026 Krasnoyarsk, Russia

YU.B.YERMASHKEVICH, A.V.BAKERKIN, I.S.GASHKIN, V.I.YEFIMKIN,
A.N.ZAKHAROV, I.V.ZNAMENSKY, V.E.TOLSTONOZHENKO,
Space Instrumentation Institute
Aviamotornaya 53
111250 Moscow, Russia

V.N.POCHUKAYEV, V.D.KUSKOV, I.V.BIRYUKOV, E.L.NOVIKOVA, A.A.PESHKIN
Space Flight Control Centre
Pionerskaya 4
141070 Kaliningrad, Moscow District, Russia

ABSTRACT. The results of an initial technical design of the AIST spacecraft and payload are presented. The spacecraft design is subjected to the main requirement: to supply the smooth rotation. Two telescopes are symmetrically placed around central beam combiner unit. The fine adjustment of the light pressure centre position by means of special-purpose sails is proposed. Scientific objectives of the project are the implementation of astrometric survey of the sky and obtaining a series of star position catalogues with milliarcsecond accuracy, including a second epoch of Hipparcos/Tycho catalogues. The survey list will consist of nearly 10-15 million stars brighter than 15th magnitude.

1. INTRODUCTION

The AIST space astrometry project [1] is supported by scientific groups of researchers from Russian organizations (Pulkovo Observatory, Institute of Applied Mechanics, Space Instrumentation Institute and Mission Control Centre). The technical possibilities to realize AIST space mission have been estimated. Pre-launch Status of Hipparcos mission [2] has been taken into account as the prototype. Development of

I.I. Mueller and B. Kołaczek (eds.),
Developments in Astrometry and Their Impact on Astrophysics and Geodynamics, 415–420.

the prototype consists of optimization of spacecraft configuration for improving its dynamic properties, in upgrading scanning mode for depressing the systematic and accidental errors, and in using two telescopes with more powerful optics and registration system. An engineering paper was prepared by the institutes mentioned above to fix the main technical decisions and to initialize the technical design stage. The short review of the basic scientific and technical properties of the mission is the aim of this paper.

The minimal goal of the mission is to obtain the astrometric catalogue with milliarcsecond (mas) accuracy for at least 400 000 stars over the epoch of approximately 2003, including the Hipparcos list. The output catalogue is planned to be driven from angular distances between program objects which are measured with accuracy better than 5 mas. The error on level of 1 mas can be deduced for positions of stars brighter than 14th magnitude distributed on sky with density greater than 10 stars per square degree. With 3.5 years of operation using the image dissector tube one can obtain also parallaxes and proper motions with the same accuracy and for Hipparcos stars it is possible to improve proper motions down to 0.3 mas. An astrometric and photometric surveys are also planned with positional accuracy of 10 mas in U, B, V, R colors and with density greater than 25 stars per square degree. Middle wave band photometry is discussed to be made instead of UBVR-photometry as the first one gives more detailed characteristics of stars. But the instrument configuration with using a CCD micrometer is under consideration which allows to enlarge list of stars and star-like objects up to 10-15 millions with the same accuracy of 1-2 mas supplying the implementation of the optimal goal of mission.

2. REQUIREMENTS TO THE MISSION

The requirements to the spacecraft and payload depend on achieved technological experience and could be formulated for the mission as follows.

* The scientific measurements on the base of transit principle need the smooth rotation of spacecraft on at least a quarter of revolution in free drift with spin axis deviation from its schedule position that should not exceed 20 of arc minutes.
* The angle between spin axis and direction to the Sun should be up to 60 degrees which improves precision for all results.
* Optics should be of diffraction quality within field of view of one square degree, and collected light should be sufficient to provide signal to noise ratio of about 5 for stars of the 14th magnitude.
* To reduce systematic and accidental errors of periods correlating with basic angle it is desirable that the instrument should consist of two telescopes with different optimal basic angles, [3].
* Micrometer should provide the spin value determination with accuracy of about 0.01 mas/s simultaneously with star abscissae determinations.
* Geostationary orbit seems to be the most optimal one for the spacecraft, but quasi equatorial orbit with 2-3 degrees of inclination and without longitudinal drift is also acceptable.
* The life period of the mission should be not less than 3.5 years.

3. THE PAYLOAD AND SPACECRAFT CONFIGURATION

Two variants of Schmidt telescope were estimated for AIST: cathadioptric one with aspheric correcting plate and the full reflective one with inclined mirror. Both variants have aperture of nearly 400 mm and focal length 2500 mm. The first has the field of view $2w=1^\circ$ and the second - 12°.

Requirements to manufacturing the inclined aspheric planoid are very strong, and optical scheme of two telescopes with correcting plates K_1, K_2 (diameter is 389 mm) and with single beam combiner unit (400mm×400mm in dimensions) is proposed for implementation, (Fig.1). Optical units are fixed to a hard membrane Q of 3200 mm in diameter. Cylindrical volume of 1200 mm height with optics has stable temperature. All optical units must be made of material with a very low temperature index. On the H-level the beam combiner BC which specified standard angles $\gamma_1=74^\circ$ and $\gamma_2=87^\circ$ is attached to the membrane.

The image of the fields S_1,R_1 and S_2,R_2 from the sky falls onto the BC then mixed beams are directed through correctors K_1,K_2, respectively. Flat mirrors A_1,A_2 direct the combined light to the L-level through holes in the membrane to inclined flat mirrors m_1, m_2 and to main spherical mirrors M_1, M_2 of 477 mm in diameter. In focal surfaces F_1, F_2 there are two micrometers G_1 and G_2 . All optical components are arranged as symmetrically as possible. The beam combiner BC is proposed to be made by coagulation of two lightened optical blocks. The BC central position inside the spacecraft is chosen to minimize its possible mechanical and temperature deformations.

In the engineering paper the Hipparcos-like construction of the micrometer was discussed to be used in the AIST mission, but four dissector tubes in every field of view are proposed to increase productivity. Alternative variants with using CCD are in consideration as the new CCDs with satisfactory parameters become available now due to the technological progress. CCD allows to increase productivity of the micrometer up to 200 stars per frame without essential changing of information flux from board of the spacecraft ,[4],[5].

Principle requirement to the spacecraft is smooth movement during full rotation period. One may subdivide it to two technical requirements:
(1) stability of the spin rate,
(2) positional stability of the rotation axis on the sky during the period of scanning.
The main technical decisions of it are:
* disk is the best shape which supplies the first requirement,
* geometry and mass symmetry of the spacecraft with particular ratio of the principal moments of inertia, proper choice of cover features optimized to minimization of disturbing light pressure reaction can supply the second requirement,
* the provision of the possibility for fine correction of light pressure centre position with help of sail features of the cover to make this centre coincided with centre of mass.

The spacecraft is formed in three-level arrangement (Fig.2,(a)).

Scanning plane is formed on the level H, the main mirrors are in the middle level L, and the service units are mounted in the level T, turned to the Sun. The cylinder of 3000 mm diameter, and of 1200 mm height forms the technological space for scientific payload. It is placed in the shadow of the solar panels with surface of 30 m^2.

On the external planes of the H and T levels the boosters of two types are mounted for three-axes orientation. The first type (hydrazine booster with the specific trust 0.1 N) is used on the stage of final formation of orbit and then stifled for exclusion of leakage; it can be used again only under emergency situation. The second type of booster (plasma booster with the specific trust adjusted in the limits of 0.001-0.01 N) is used in the operating conditions. The arrangement is subordinated to the mass symmetry principle with particular ratio of the principal moments of inertia relative to associated coordinate system axes: J_x=3200, J_y=3400, J_z=7000 ($Kg*m^2$). The solar panels are spread out on the angle $90^\circ+\theta_3$, $\theta_3 \approx 2^\circ$, and fastened along the perimeter as the rigid membrane to depress the amplitudes and periods of the vibration. The exterior surface turned to the Sun was modeled by the set of geometrical figures. The dependence of the residual disturbing moment M_s on the angle φ between the spin axis $-\bar{\omega}$ and the Sun direction $\bar{s}$ is shown on Fig.2,(b). The curve 1 is for cylindrical surface with radius R=1500 mm, the h_o variation being not feasible. The curve 2 - for the high reflecting surface formed by cylinder with attached cut cone under r=250 mm, $\theta_1=30^\circ$, and the curve 3 for the same lustreless surface. The main regime of apparatus is supposed to be inclined on $\varphi \approx 60^\circ$, but the full interval of 0° - 60° is operating range.

The best stability and control ability is seen for the curve 2. For fine control the propellant effect of sail action from the strips l_3 under the butts of panel surfaces and from the boundary sail surfaces by variation of angles θ_2, θ_4 is designed. The most common preliminary estimation of the stability for the spin position on the sky and in time are shown on the Fig 2 (c),(d), respectively.

4.CONCLUSION AND ACKNOWLEDGEMENTS

The stage of the comprehensive researches and technical design is initialized as the first estimations show the good potential of the project.

The authors are grateful to Dr.B.I.Vlasov for constructive discussions. Of particular value are the comprehensive interest, consultations and criticism from Prof.E.Hoeg and Dr.L.Lindegren, to whom the authors are greatly acknowledged.

5. REFERENCES

1. Chubey,M.S., Makarov,V.V., Yershov,V.N.,et al.,(1990),in 'Inertial Coordinate System on the Sky', *Proc.IAU Symp.141*, Leningrad, 77.
2. 'The Hipparcos Mission.Pre-Launch Status', *ESA SP-1111*,(1989),**1-3**.
3. Makarov,V.V.,(1992),'Periodical Errors of Hipparcos Star Abscissae', Abstract, in the present volume.

https://doi.org/10.1017/S0074180900173632 Published online by Cambridge University Press

4. Høg,E.,Lingegren,L.,(1992),'A CCD Modulation Detector for a Second Hipparcos Mission', Abstract, in the present volume.
5. Yershov,V.N.,(1992),'Focal Plane CCD Micrometer for AIST Astrometric Satellite', Abstract, in the present volume.

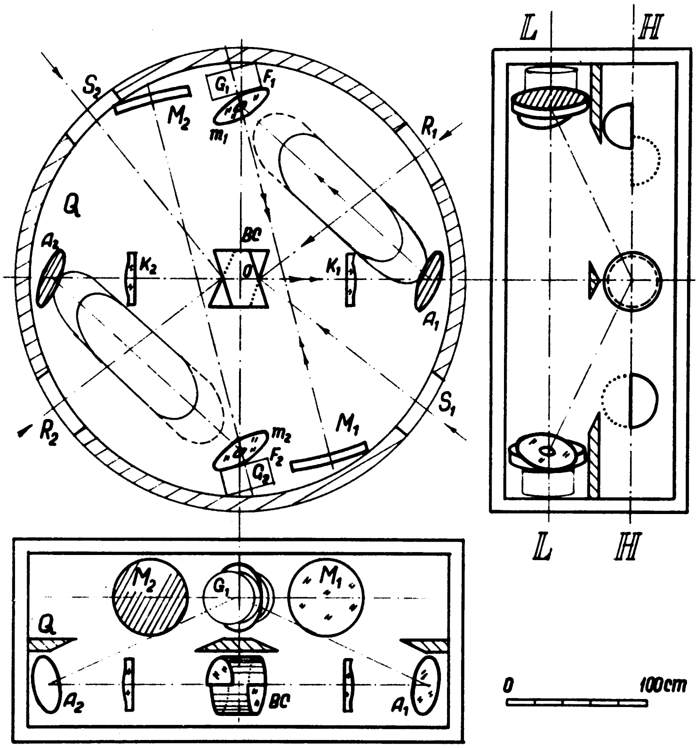

Fig.1. Configuration of the AIST telescopes.

Two cathadioptric Schmidt telescopes with mirrors M_1, M_2 each being of 477 mm in diameter, 2500 mm focal length, with correcting plates K_1,K_2 of 389 mm in diameter, and basic angles $\gamma_1=74^\circ$, $\gamma_2=87^\circ$ that are formed by beam combiner BC of 400 mm in diameter and 400 mm in length all these elements are identifying the optical scheme. The flat folding mirrors A_1,A_2, and m_1,m_2 are used to form the two-level arrangement attached to the rigid membrane Q of 3200 mm in diameter.

https://doi.org/10.1017/S0074180900173632 Published online by Cambridge University Press

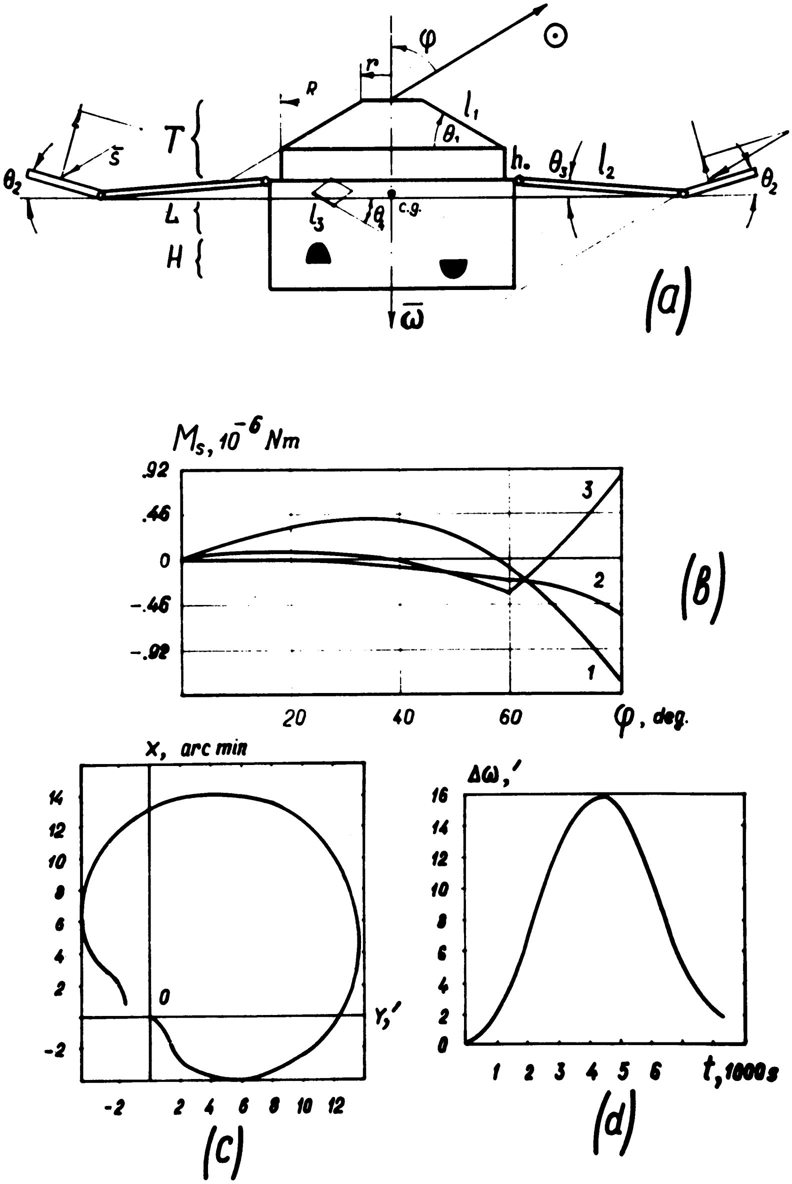

Fig.2. General view and dynamical features.

(a) - the geometry of the cover: H and L levels are alwais in the shadow from the solar pannels l2; (b) - the residual disturbing moment for the surface on level T: (1) - for cylindrical surface, (2) - for the high reflecting cylinder headed by cut cone, and (3) - the same for lustreless surface; (c),(d) - the spin position drift during the full turn of spacecraft