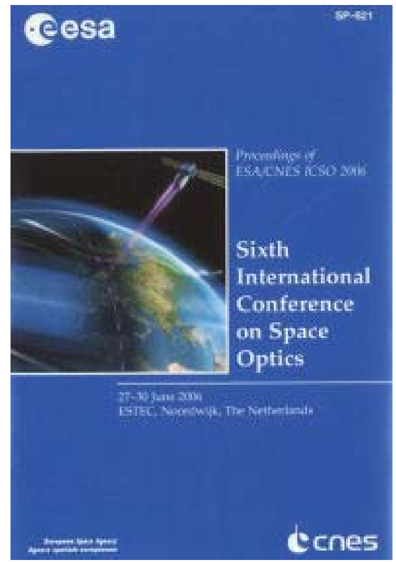
International Conference on Space Optics—ICSO 2006

Noordwijk, Netherlands

27–30 June 2006

Edited by Errico Armandillo, Josiane Costeraste, and Nikos Karafolas



Dobson space telescope: development of an optical payload of the next generation

Tom Segert, Björn Danziger, Daniel Gork, Matthias Lieder

International Conference on Space Optics — ICSO 2006, edited by Errico Armandillo, Josiane Costeraste, Nikos Karafolas, Proc. of SPIE Vol. 10567, 105673E · © 2006 ESA and CNES
CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2308063

DOBSON SPACE TELESCOPE – DEVELOPMENT OF AN OPTICAL PAYLOAD OF THE NEXT GENERATION

Tom Segert[(1)], Björn Danziger[(1)], Daniel Gork[(1)], Matthias Lieder[(1)]

[(1)] Dobson Space Telescope, TU-Berlin Department of Astronautics, Marchstr. 12- Sekr. F6, 10587 Berlin, Germany
Email:info@dobson-space-telescope.com

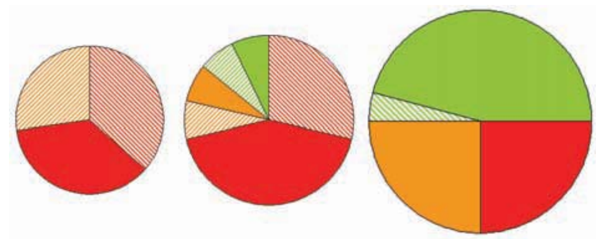
ABSTRACT

The Dobson Space Telescope (DST) is a research project of the Department of Astronautics at the TU-Berlin. For Development and commercialisation there is a close cooperation with the network of the Berlin Space Industry (RIBB). Major Partner is the Astro- und Feinwerktechnik Adlershof GmbH a specialist for space structures and head of the industry consortia which built the DLR BIRD micro satellite. The aim of the project is to develop a new type of deployable telescope that can overcome the mass and volume limitations of small satellites. With the DST payload micro satellites of the 100kg class will be able to carry 50cm main mirror diameter optics (→ 1m GSD). Basis of this technology is the fact that a telescope is mainly empty space between the optical elements. To fold down the telescope during launch and to undfold it after the satellite reached its orbit can save 70% of payload volume and 50% of payload mass. Since these advantages continue along the value added chain DST is of highest priority for the next generation of commercial EO micro satellites. Since 2002 the key technologies for DST have been developed in test benches in Labs of TU-Berlin and were tested on board a ESA parabolic flight campaign in 2005. The development team at TU-Berlin currently prepares the foundation of a start-up company for further development and commercialisation of DST.

1. EARTH OBSERVATION WITH SMALL SATELLITES

During the last years the number of small satellites have been dramatically increased. Since 2001 there is a steady growth of 25% per year. Within these numbers three major trends can be observed:

- Trend for higher and higher resolution and high resolution EO microsats increase their market share in absolute numbers
- Increase of operational and commercial instead of experimental systems
- Dramatical increase of launched micro satellites due to families of similar satellites in constellations



Red = low resolution (less than 30m GSD)
Orange = medium resolution (better than 30m GSD)
Green = high resolution (better 5m GSD)
Hatched color = experimental system

Fig. 1. Development of the market for EO microsats [9]

1.1. Prospects and Limitations

Thanks to miniaturisation of electronics and the use of modern COTS technology today's state of the art micro satellites can compete in many areas with standard large satellites. They can obtain imagery with resolutions up to 2,5m GSD in a comparable amount and quality but with a much lower price. In addition the low cost for small satellites enables constellations which offer very fast revisit times unknown to a single large satellite. This makes them very attractive for many users and is the reason why their numbers have increased that much during the last years. Unfortunately even the smallest microchip can not overcome basic optic principles: to achieve high resolution one needs a large aperture telescope which does not fit the given space of small satellites.

With a GSD of 2,5m for a 120kg microsat classical telescope technology reached its limits. For higher resolutions the user faces the following dilemma:

- Cost reduction = miniaturisation <u>but</u>
- Small systems = small less capable payload
- High resolution = large payload = large satellite

→either cost effective <u>or</u> high resolution (better than 2,5m)

Proc. '6th Internat. Conf. on Space Optics', ESTEC, Noordwijk, The Netherlands, 27-30 June 2006 (ESA SP-621, June 2006)

2. DEPLOYABLE TELESCOPES

The problem is part of the solution: a telescope is mainly empty space between the optical elements. This space is needed for observation but useless during launch. The deployment of the telescope in space can save 70% of payload volume and 50% of payload mass compared to classical non deployable telescopes.

A satellite based on a deployable telescope has

- 3 times higher GSD (at the same cost) than today's state of the art micro satellites
- 10 times less cost (at the same GSD) than today's state of the art mini and large high resolution EO satellites

Since these advantages continue along the value added chain only satellites with deployable optical payloads can serve the end users needs for low cost and high resolution imagery.

Currently worldwide 5 teams develop deployable optics. The Dobson Space Telescope research team at TU-Berlin is among this avant-garde.

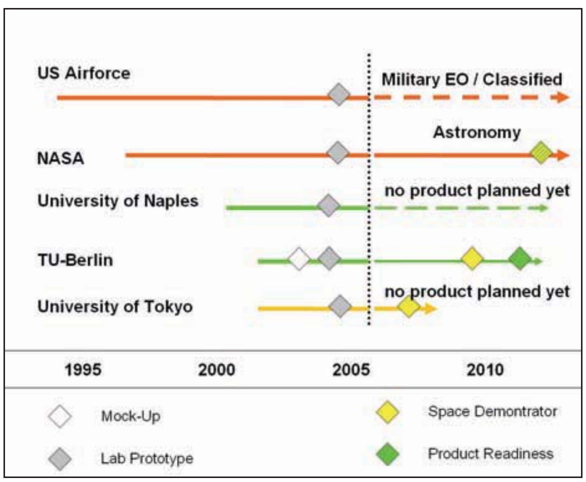


Fig. 2. development status of deployable telescopes

Within the developments for deployable optics two different approaches exist:

- deployable mirror technology for large satellites
- deployable structures for small satellites

Whereas NASA [2] and US Airforce [3] rely on a very complex system based on deployable mirrors the DST team at TU-Berlin, the MITAR Team at University of Naples [4] and the PRISM [5] Team at University of Tokyo rely on a system with non deployable mirrors but deployable telescope structures.

- the limiting factor for very large aperture systems (>5m main mirror diameter) is the rocket fairing
- the limiting factor for small satellite payload is the telescope length

→ deployable mirrors are unnecessary for small satellites

2.1. deployable telescopes for small satellites

The three teams which work on payloads for small satellites have two different approaches:

- Deployment and optical fine adjustment (collimation) → Dobson Space Telescope
- Deployment and focus only → MITAR, PRISM

The renunciation of a in orbit collimation system helps to reduce the system complexity but limits the optical performance of the payload dramatically.

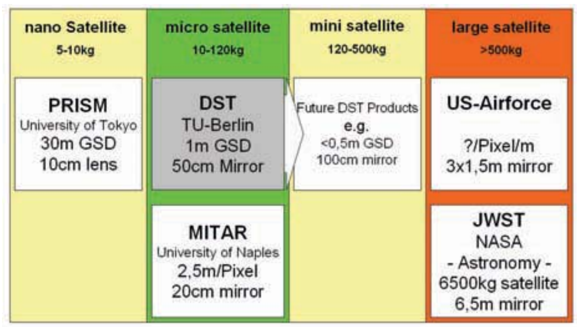


Fig. 3. classes of deployable optics

None of the competitors of DST focuses on high resolution payloads for micro satellites. Therefore the DST payload will be the only product to suit the needs for 1m GSD in the micro satellite market.

3. DOBSON SPACE TELESCOPE

The Dobson Space Telescope [1] Payload is designed for the next generation of high resolution micro satellites. Table 1 compares the DST payload to the RAL-CAM of SSTL TOPSAT and the OHRIS of Orbview 3. Both payloads are state of the art for today's micro and mini satellites.

	DST	RalCam [10]	OHRIS [11]
Telescope	50cm f/8 Cassegrain	20cm TMA	45cm f/8 Cassegrain
GSD (pan/ms)	1m / 4m	2,5m / 5m	1m / 4m
Channels (pan/vis/nir)	1 / 3 / 1	1 / 3 / 1	1 / 3 / 1
Swath (km/pixel)	8km / 8kpx	15km / 6kpx	8km / 8kpx
Scenes/Orbit	128	1	128
Mass	32kg	32kg	60kg
Volume	0,1m³	0,2m³	0,33m³

Table 1 DST payload vs. RalCam and OHRIS

3.1. Optical concept

DST will use a straight forward optical design: two mirror modified cassegrain with a lens based field corrector. This design rather than a complex TMA was chosen for DST in order to keep the deployment and collimation efforts low.

The later product DST payload will feature a 50cm f/8 deployable telescope which is the maximum possible aperture for a standard micro satellite. Nevertheless TOPSAT and other microsat missions have shown that secondary payloads can comprise larger volumes than the standard 600x600x800mm defined by Ariane5 ASAP. Depending on the market needs there are even bigger versions of the DST payloads possible. The technology itself is easily scaleable for any main mirror aperture ranging from 30cm to 3,5m.

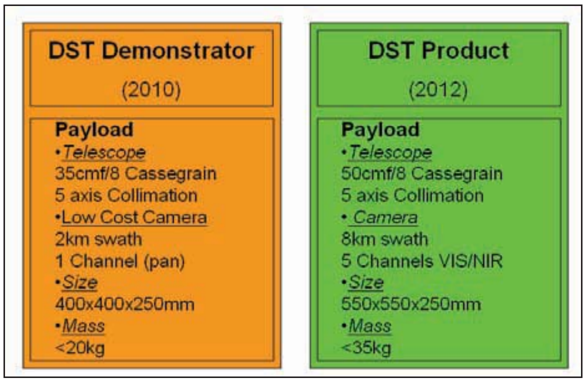


Fig. 4. DST Demonstrator vs. DST Product

For cost reasons all existing and future lab versions as well as the first space prototype will only have 35cm aperture. This will allow 1,5m GSD. Besides the scaled optical system the DST Demonstrator will be identical to the later DST product. A detailed comparison of those two systems can be found in Figure 4

3.2. Key Technologies

For realisation of DST two key technologies are needed:

- ultra precise deployment mechanism
- automatic in orbit optical fine adjustment (collimation)

Since 2002 the key technologies for the DST payload have been developed in the labs of TU-Berlin and tested under zero-g conditions during an ESA parabolic flight campaign in 2005.

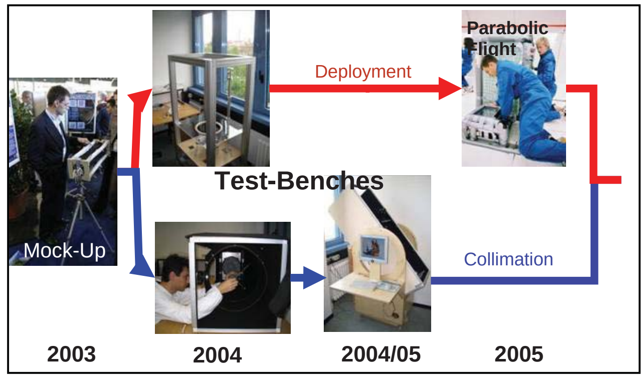


Fig. 5.Test benches of DST

The project is now at the end of the lab phase. The key technologies which have been tested in separated test benches will now be integrated into one combined test bench.

3.2.1. Deployment mechanism

In contrast to the competitors which rely on lightweight spring mechanisms for telescope deployment DST has chosen a much more rigid structure. The DST structure which is based on trusses and hinges is much stiffer and much more precise. Testing of the structure on the parabolic flight campaign in 2005 has shown that the already the current lab prototype fulfils most of the requirements needed for the later space version. An evolved version of this mechanism currently undergoes a frequency analysis. The structure is tested both in deployed and non-deployed configuration. This work is done in cooperation with the institute of mechanics at the TU-Berlin. After completion the finalised deployment mechanics will be integrated in the combined test bench at the end of this year.
The deployment technology of DST is patent pending.

3.2.2. Collimation mechanism

An optical telescope is a very precise instruments. Even minor displacements of the optical elements will have dramatic effects on the image quality. Since no deployment mechanism can be as perfect as needed for the telescope. The optical system needs to be fine adjusted after deployment in order to assure maximum image quality.
The collimation mechanism which is basically 5 axis micro actuator which is placed behind the secondary mirror is designed to act as the mediator between the possibilities of the deployment mechanisms and the requirements of the optical system. In addition to first in orbit collimation the mechanism can be used to collimate the telescope at any time during the mission. This is a great advantage over classical non deployable telescopes without collimation actuators.

3.3. Satellite Bus requirements

Due to the very high resolution of DST the requirements are very challenging.

- >32kg payload mass
- 600x600x300mm payload volume
- 35W average / 150W peak power (including X-Band downlink)
- <1 arcmin pointing accuracy
- **<0,125arcmin/s jitter**
- <10arcsec pointing knowledge
- state of the art payload computer
- 150Mbit/s X-Band Downlink

Three potential European micro satellite busses have been identified as a potential carrier for DST:

- DLR BIRD/TET [6]
- SSTL Enhanced Microsat 100 [7]
- CNES Myriade

Except for ACS Jitter all of these busses are suitable for DST. Since these busses demonstrated jitter performance between 1-2 arcmin/s which is by the factor of 8 worse than required all of them need improvements. DST has chosen the BIRD/TET Bus as preferred platform for DST payload. Nevertheless the later product will be available to any interested customer and bus able to suit the needs of the DST payload.

3.4. Schedule

After completion of the test with the lab models the development of a first DST space demonstrator is planned. For the development and commercialisation of this demonstrator payload the development team at TU-Berlin prepares a start-up company.

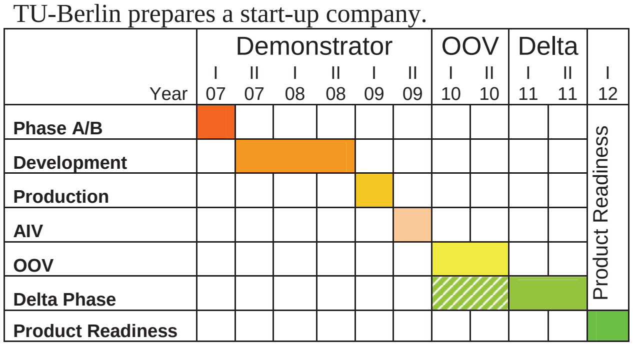


Fig. 5. Schedule for DST Development

According to the schedule the following milestones will be achieved:

- finalising of the lab prototypes – 2006
- foundation of DST company – 2006/7
- demonstrator ready for on orbit verification (OOV) – 2010
- Product readiness – 2012

3.5. Strategic partners

The development of the DST payload is based on three major columns:

- DST Company – start-up company of the DST development team at TU-Berlin)
- TU-Berlin – Department of Astronautics, Institute of Mechanics and others as development partners
- Astro- und Feinwerktechnik Adlershof GmbH – development partner for DST structures and interface to the satellite bus

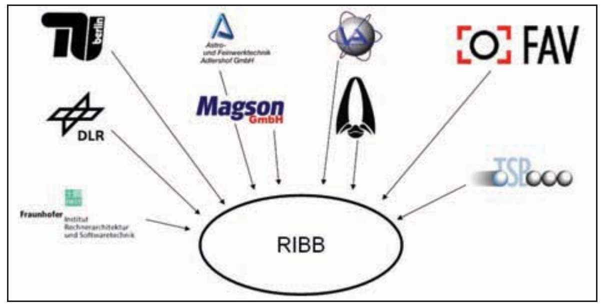


Fig. 6. RIBB

The DST development is part of the Raumfahrtinitiative Berlin Brandenburg (RIBB). RIBB is the network of the Berlin Space industry. The aim of RIBB is to coordinate, promote and to act as a hub for the Berlin space activities. Figure 6 shows the partners of RIBB.

4. CONCLUSION

With a GSD of 1m the DST payload will be the most capable micro satellite payload in the medium term. Its key technologies have been demonstrated in the labs of TU-Berlin and on board an ESA parabolic flight campaign. Based on the RIBB network the DT development team currently prepares a start-up company to further develop and commercialize DST technology.

5. REFERENCES

[1] Dobson Space Telescope Homepage http://www.dobson-space-telescope.com
[2] James Webb Space Telescope Homepage http://www.jwst.nasa.gov/
[3] US Airforce Deployable Telescope homepage http://www.dod.mil/transformation/articles/2006-01/ta012406a.html
[4] Mitar homepage http://www.corista.unina.it/asie.html
[5] Prism Homepage http://www.space.t.u-tokyo.ac.jp/prism/main-e.html
[6] DLR BIRD, http://www.dlr.de/os/forschung/projekte/bird/bird_01.html
[7] SSTL Homepage, http://www.SSTL.co.uk
[8] Afordable Space Mission Studie mit TET, DLR 2005, http://www.dlr.de/os/forschung/projekte/asm
[9] T. Segert, Businessplan Dobson Space Telescope
[10] RalCam Spec, EO Portal http://directory.eoportal.org/pres_TopSat.html
[11] OHRIS spec, EO Portal http://directory.eoportal.org/pres_OrbView3.html