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WHERE SIZE DOES MATTER

Foldable Telescope Design for Microsat Application

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ABSTRACT
The DOBSON SPACE TELESCOPE Project (DST) at the Technical University of Berlin (TUB) believes that micro satellites can be a challenging competitor in the high resolution remote sensing market. Using a micro satellite as basis for a remote sensing platform will dramatically reduce the cost for the end users thereby initiating the predicted remote sensing boom. The Challenging task is that an optic required for a GSD smaller than 1m is much bigger than the given room for secondary payload. In order to break the volume limits of hitchhiker payloads the DST team develops an optical telescope with deployable structures. The core piece of DST is a 20 inch modified Cassegrain optic. Stored during ascend the instrument fits in a box measuring 60 x 60 x 30cm (including telescope and optical plane assembly). After the satellite was released into free space the telescope unfolds and collimates automatically.

1. INTRODUCTION

The DOBSON SPACE TELESCOPE Projects is a student initiative at the TU-Berlin [1]. It is our aim to develop foldable optics for micro satellite application. The Idea is to overcome the volume limits of hitchhiker payloads by disassembling the telescope during transport and reassemble it for observation. This technology will enable satellites of the 100kg class to carry 20inch mirror optics and make them to a serious competitor in the state of the art remote sensing market. Our Project is part of the micro satellites activities at our university (the TUB-Sat family [2]). It is supervised by Prof. Briess the former project manager of the DLR BIRD mission [3].
The core group consist of 3 master students from the TU-Berlin. Due to the high complexity of the topic we tried to acquire external expert knowledge from the beginning. With the help of nearly a dozen external experts of various fields we formed a science network. Therefore the DOBSON SPACE TELESCOPE has become a dynamic and well known project in the micro satellite business.

1.1 Market Development

Satellite based remote sensing was an integral part of space business from the beginning. The first military systems were followed by governmental systems (none military). Both military and institutional systems were designed from engineers with nearly unlimited budgets. The problem is that nearly all commercial remote sensing systems derive from these designs and design strategies. Subvention which has made space business possible in the 20th century has become the biggest flaw of space commercialisation in the 21st. In fig 1 an overview about the existing commercial remote sensing systems is given.

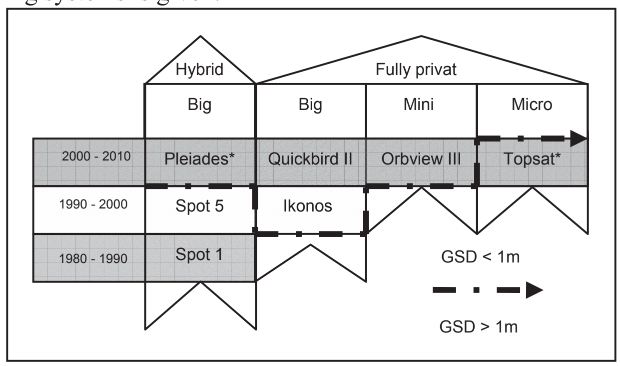


Figure 1 commercial HR Systems

Even today's "fully private" systems cannot survive alone. Massive state support is needed to keep them alive. This has two negative outcomes

- A reduced need for new more cost effective systems
- With the few big systems alive the price per scene is kept high. Only few (governmental) users can afford it. For this reason the market stays low

To access new markets the price for the end user has to drop significantly. Therefore the number of attendees to the market has to increase from a handful to some ten competitors. With conventional satellite design this cannot be done.

1.2 Cost reduction strategies

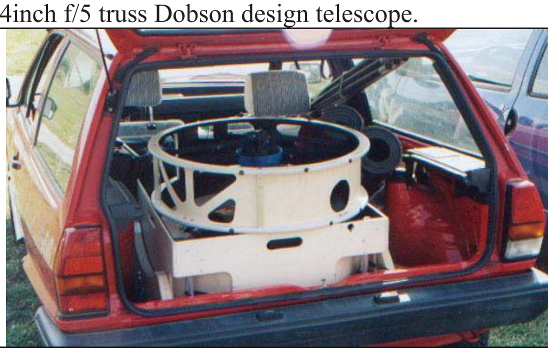
Micro satellites can be the key to success. In over 120 missions during the last decade they have shown their ability to handle complex mission scenarios [4]. But not only miniaturisation is needed to build satellites for a reasonable price also some sort of "mass production". This has to be done to reduce the enormous price per kg for space hardware. Another needful thing is to abandon the "space proven technology only" design strategy. With 5 successful TUB Sat's the TU-Berlin has proven that COTS and reduced redundancy does not necessarily decrease the satellites reliability.

1.3 Challenges

Despite a favourable optic system all technologies needed for state of the Art remote sensing have been demonstrated on small satellites. Yet the main challenge remains: Micro satellite does not only mean weight but also volume limitation. In the typical 60 x 60 x 80cm Box no telescope with an aperture greater than 12inch will fit in [5].

2. IDEA

Facing challenges of micro-sat business means putting the focus on the telescope design. As long as aperture is coupled to length of telescopes; the maximum size of the telescope is limited. The answer lies within the problem: a telescope is mainly empty space between the optical elements. If the needed space for the telescope could be compressed it would be possible to avoid this limitation. The problem of micro satellites optics draws interesting parallels to amateur astronomy. You'll need the biggest telescope that fits in the boot of your car. The answer to both the micro-sat and the amateur astronomy problems is Truss Dobson design. This means the ability to fold the telescope for transport and unfold it for observation. This technology has proven to be a simple and reliable solution on earth. It is the aim of the Dobson Space Telescope project to adapt it for space application. Fig. 2 shows a 24inch f/5 truss Dobson design telescope.



transport configuration

telescope ready

Figure 2 Truss Dobson Telescope [6]

3. DEPLOYABLE STRUCTURES

Telescopes with deployable structures can be classified in two groups: the foldable mirror and the foldable telescope technology (without deployable mirrors). DST as a low-cost mission belongs to the second group. The shape of the focal plane assembly and the main mirror is fixed. Only the booms which place the secondary mirror are deployable. Despite the fact that a system with deployable mirrors and booms can achieve higher compression rates the team believes that this is a good trade off for a micro satellite. The deployable mirror technology that will be used in the James Webb telescope is not mature.

3.1 Scalability of telescope design

It was part of our studies to evaluate the scalability of this technology in order to find out which satellite class to concentrate on. In fig. 3 the outcome of this evaluation is shown: the advantage of deployable structures increases with an increased aperture. It is clearly visible that the capabilities of the foldable telescope technology are between the classical solid telescopes and the foldable mirror technology. The bigger a telescope gets the more vulnerable it is. While a 4inch telescope may not need any mechanisms at all bigger telescopes need at least an adjustable focus to compensate thermal

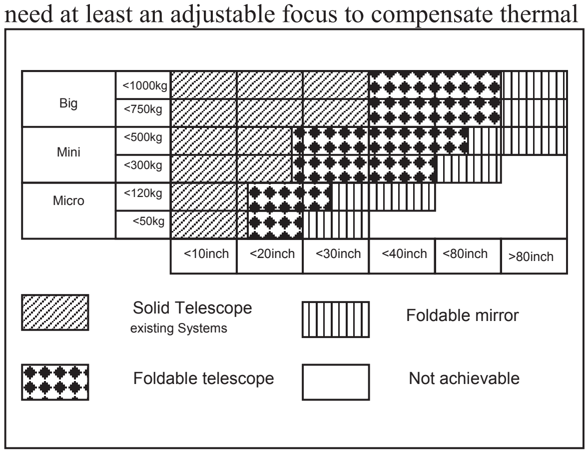


Figure 3 mass of satellite vs. telescope aperture

effects. The biggest solid telescopes even need in-orbit collimation, too (mainly astrophysical instruments). Due to their sheer size and the increasing structural stress during launch increases. Stable collimation cannot be assured.

3.2 Applications for foldable telescopes

Although the Dobson Space Telescope is designed as a micro satellite for earth observation and NEO survey the technology of foldable telescope design offers advantages for other satellites classes and missions, too. For any satellite system needing apertures greater than 12inch while lacking appropriate mass, volume and funding foldable telescope technology is useful. Possible missions may vary from a successor of the mars express orbiter to low-cost astronomy missions.

Especially astrophysical missions are an interesting application for the foldable telescope technology. The main problem of Hubble and its successor the James Webb Space Telescope (JWST) is that there is only one of them. As a replace for the two cancelled Hubble service mission it would be possible to build a fleet of low-cost sky observatories carrying 2m mirrors optics. This would enable much more astrophysical research. Furthermore this opens ways for specialized or long duration missions without blocking the workhorse of all other astronomers.

3.3 Process of unfolding

The telescope will be unfolded with the deployment of the booms. After this the secondary mirror is about 1,5m depart from the main mirror but not exactly in the right position. This will be done during collimation. To deploy the booms many different technologies already space proven can be used. From booms with hinges to inflatable structures everything is possible. The low cost approach in mind our team tries to avoid technologies that need special operation conditions during ground testing (such as simulated zero g or vacuum).

3.4 Collimation

Secondly micro actuators will fine adjust the position of the secondary mirror and thereby collimate the telescope. The fine adjustment can be seen as a mediator between the requirements of the optical system and the abilities of the booms. The more precise the booms work the less difficult is collimation. Our team develops an automated collimation mechanism based on lasers and reflectors as sensors and piezo elements as actuators. The mechanism is sketched in one of our studies [7]. The last step is the focussing of the camera system. After this the Dobson Space Telescope is ready. In order to compensate thermal deformation of the telescope structure the collimation and focussing can be performed at any time during the mission to insure stable image quality. The boom deployment itself will be irreversible.

4. VISION

Besides developing the technology the DST team tried to figure out what possible satellite and missions can be done with a micro satellite carrying a foldable telescope. We sketched a time shared sky observatory the Dobson Space Telescope [8]. This micro satellite carries a 20inch modified cassegrain reflector as its main instrument.

4.1 Mission

The DST satellite will have two different missions: remote sensing during sun phase and NEO survey during earth shadow. This dual mission will increase the duty cycle of the satellite by expanding its exploitation into the former useless eclipse time. There will be two cameras. One camera is placed in the primary and one secondary focus to fulfil the different requirements of the mission. Switching between the two modes can be done by flipping the secondary mirror in and off the optic path. In and fig. 4 the main features of DST and general procedure for readying in space are shown.

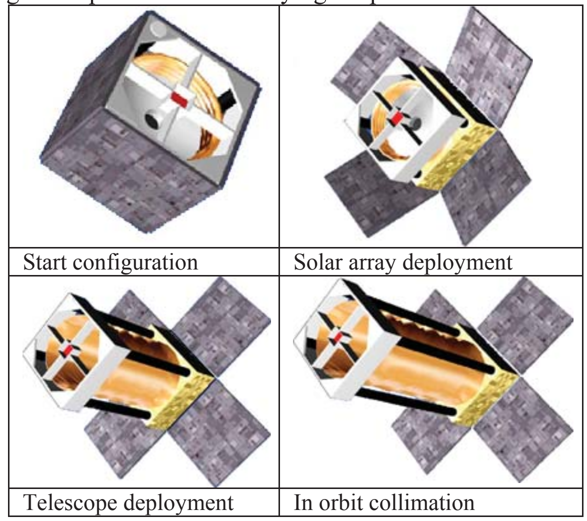


Figure 4 DST in Orbit

4.2 Foldable vs. solid

The best way to figure out the advantages of a foldable telescope is to compare it with a classical one. We have chosen Orbview III (OV3) from Orbital [9] as the reference for commercial remote sensing with small satellites. In the group of three commercial satellite systems with a GSD of 1m or better is it the most comparable to DST. Tab. 2 compares the two satellites. In order to insure comparability the DST is designed to have the same technical abilities as OV3. The most obvious change is the renunciation of an orbit control system. This prohibits the use of an orbit lower than 550km.

	Orbview III	DST
general Features		
Orbit	470km SSO	550km SSO
GSD (pan/msp)	1m / 4m	1m / 4m
Swath	8km	8km
mass	300kg	100-120kg
size (stored)	1x1x2m	0,6x0,6x0,6m
size (operational)	1x1x2m	0,6x0,6x2m
Payload		
Instrument	18” modified Cassegrain	20” modified Cassegrain
mass	~70kg	<50kg
size (stored)	unknown	0,6x0,6x0,3m
size (operational)	unknown	0,6x0,6x1,7m
Bus		
ACS	3 axis stabilised	3 axis stabilised
Orbit control	yes	no
Downlink	150Mbit/s	150Mbit/s
mass	~200kg	~60kg
size	unknown	0,6x0,6x0,3m

Table 1 Comparison OV3 vs. DST

To compensate the reduced spatial resolution (a result of the higher orbit) the aperture and the focal length of DST’s main mirror is 17% larger.

The biggest advantage of the DST System is that it only weights about one third of the OV3 Satellite. This has mainly 3 reasons

- DST uses a micro satellite Bus without an orbit control system
- During the launch the telescope is folded. The stress level is lower and there is no possibility of losing collimation since the telescope is collimated in orbit. Therefore the telescope structure can be much lighter.
- With a lighter instrument and smaller forces the structures of the whole system can be designed smaller and less rigid.

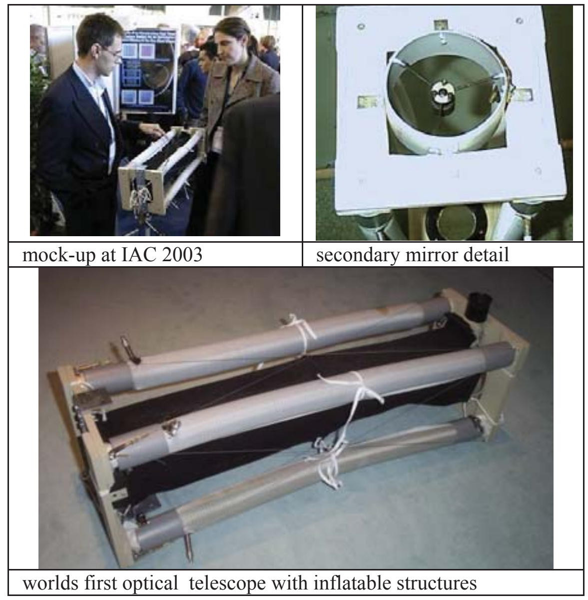
The increased number of mechanisms and that the telescope needs to be unfolded in orbit seams to be a slight disadvantage but this is compensated with the lower risk of vibration damage.

5. CURRENT STATUS AND OUTLOOK

With 6 TUBSat's build directly at the TU-Berlin and the DLR BIRD build at DLR Spacesensor systems in Berlin Adlershof the TU-Berlin has a wide micro-sat experience. Nevertheless building DST is a huge leap forward since the biggest optical satellite system of the TU-Berlin is the DLR TUBSat. It has an aperture of 3inch. So the decision was made to take the hurdle in several smaller steps. Fig. 5 shows the mock-up which was build parallel to the "phase A" study. It contains a 3inch f/10 Newtonian telescope. The main task of the mock-up was to get the team an idea what construction of telescopes is about. In addition it was very helpful to acquire sponsors and supporters for our vision. Currently we work on the "phase B" study. Part of this study is the construction of a lab model. This scaled version of DST will be used to test the critical technologies. We are very confident that the paper studies will be finished until End of 2004. It is planned to use the lab model as a starting point for the development of a payload to fly on a future TUBSat. With all these hurdles taken our Team will finally be able to build the Dobson Space telescope as it was envisaged in our vision.

6. CONCLUSION

The foldable telescope technology will increase the abilities of low-cost and small satellite missions but despite its origins in the amateur astronomy the design of a foldable space telescope remains a challenging task. There is no existing optical system with automatic deployment and collimation. The only comparable project known to the authors is the James Webb Space telescope of NASA which will not be ready before 2011.



mock-up at IAC 2003 | secondary mirror detail

worlds first optical telescope with inflatable structures

Figure 5 Dobson Space Telescope Mock-up

Nevertheless the DST team believes that our vision is worth taking some steps into the unknown. With 6 TUBSat's built directly at the TU-Berlin and the DLR BIRD built in Berlin Adlershof the TU-Berlin has a vast micro satellite experience. Thanks to the help of our Sponsors, the supporting Experts and Companies we believe that our project will be successful. Foldable optics on micro satellites offer huge opportunities and will therefore revolutionize satellite based remote sensing. They herald a new age of satellite based observation where everyone can afford high resolution remote sensing data.

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