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POST-FLIGHT INVESTIGATION PROGRAMME FOR THE FIRST SOLAR GENERATOR OF THE HUBBLE SPACE TELESCOPE

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ABSTRACT

The Hubble Space Telescope (HST) was launched into a 614 kilometre low earth orbit (LEO) on 24 April 1990. The HST is a joint NASA/ESA project. ESA provided two major elements towards the project one being the Solar Arrays (SA). They comprise two double roll-out wings each with two flexible blankets. The solar array was successfully deployed in orbit on 25th April 1990.
During the first years in orbit the telemetry data, both for power and dynamics, received at the ground stations have been evaluated in detail and compared with the predictions. Presently (April 1993), the solar arrays generate ≈ 4.6 Kilowatts.
The first HST servicing mission has been scheduled for the end of 1993. Together with other key instruments the SA's are also planned to be replaced . This provides a unique opportunity to study the mechanical integrity, the change of material properties and other degradation mechanisms of the SA's in detail, after being exposed to almost 4 years in LEO.
This planned post-flight investigation programme will be presented in this paper. The investigation of space debris and meteoroid particles and their distribution will be one of the major tasks and of great help to the space debris and meteoroid community in refining their models and knowledge on damaging effects of impacting particles.

1. Introduction

The Space Telescope Solar Array (STSA) is supplying the power for the joint NASA/ESA Hubble Space Telescope (HST). The STSA is a unique European development. Under the prime responsibility of the European Space Agency, a group of European contractors led by British Aerospace have developed and built the largest flexible solar generator to date. It consists of two double roll-out solar array wings (Fig. 1) which are deployable and retractable. Each wing is equipped with two solar array blankets (SAB) carrying the solar cells which are protected from each other by an embossed Kapton cushion whilst they are stowed on a common storage drum.

The solar array wings were successfully deployed on 25 April 1990 with the Space Shuttle Discovery and HST in a 614 km orbit . The deployment was carried out in two phases. Firstly, the solar arrays (initially latched parallel to the body of the HST) were rotated by magnetic stepper motors so that they lay perpendicular to the HST. Secondly the SABs were unrolled from the storage drum by bi-stem booms (Fig. 2) at either side of each blanket. They deploy a spreader bar attached to the end of each SAB.

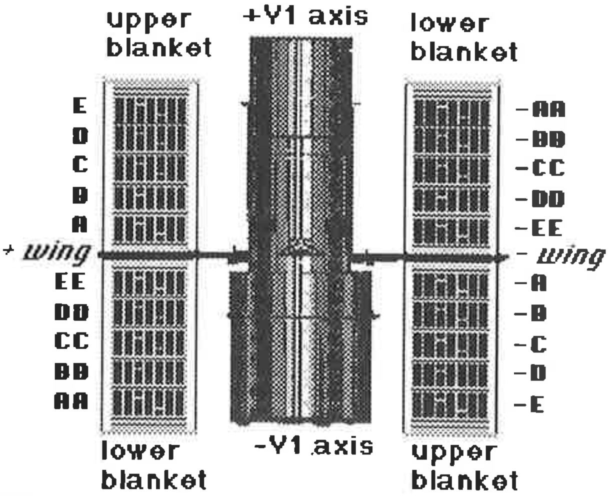

Figure 1: Solar array configuration

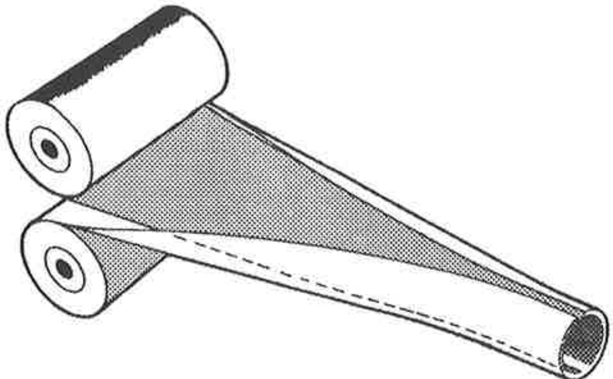

Figure 2: Bi-stem boom configuration

During the years of successful operation the solar generator provided the required power to HST with a healthy margin. NASA has scheduled the first servicing mission for the end of 1993. Together with other key instruments the SA's are also planned to be replaced. The SA's of HST will be the first solar generator brought back from space after having exposed to the LEO environment for a significant period (≈ 4 years) in a well known orbit and orbit orientation.

It is of great importance to study this generator in great detail. We will obtain extremely valuable and reliable information on numerous essential subjects, e.g. atomic oxygen (ATOX), meteoroid and space debris damage, low cycle fatigue, material degradation etc. We should also be able to explain and understand the anomalies experienced on the first solar arrays. The knowledge gained from the investigations is essential for the design of future solar generators as well as for other S/C subsystems, and also important for the space debris and meteoroid community. The total surface of the HST solar-array is about 130 m^2, and provides a unique opportunity to study the craters of impacting particles, also to assess the impacts and potential damage and to refine the current meteoroid, and debris models.

This paper is intended to give an inside into what are we about to investigate, and what kind of results we are expecting to obtain. After completion of STSA-FPLIP, further solar array hardware samples can be made available for investigations outside solar array related activities. Ideas for further useful investigations are always welcome.

2. Solar array design

The STSA is designed to survive intact for at least five years in a 600 km low earth orbit. This means that the solar arrays will have to withstand 30,000 thermal cycles between about +/- 100°C in the presence of an aggressive atomic oxygen (ATOX) environment. STSA is required to deliver at least 4.4 kilowatts of electrical power at 34 volts after two years in orbit. Actually (April 93), the solar arrays generate ≈ 4600 watts which is about 5 to 6% above the predictions.

The solar array design is only described as far as is necessary for the scope of this paper. A detailed description can be found in various previous publications (e.g. ref. 2,3).

The HST solar array has three major mechanism subsystems:

The Primary Deployment Mechanism (PDM) rotates the blanket storage drum assembly from its launch configuration to its deployed position, perpendicular to the spacecraft body. The two PDM systems are commanded simultaneously and operated by two redundant stepper motors (operating current 360 mA, nominal step frequency 4 Hz). The motors, driving through a gearbox, take approximately 8 minutes to deploy the arms through 90°, where it is held in position by an overcentre device.

The Secondary Deployment Mechanism (SDM) is activated when the wings are perpendicular to the HST body. The actuator motor for each wing drives the four bi-stem booms out (two per blanket), which in turn draw the blanket from the drum by means of a spreader bar fixed between the ends of the two bi-stem booms. A boom length compensator mechanism fixed to the ends of the spreader bars accommodates any mismatch in boom length. The double roll-out configuration requires a cushioning layer between the blankets, which protects the solar cells from breakage during launch. A tensator spring rolls this protection layer, made of embossed Kapton, onto the cushion roller during deployment. In stowed/launch configuration, the bi-stem booms are flattened and rolled onto storage spools (Fig. 2). Each boom consists of two pre-'C'-shaped elements. On deployment, the two overlapping pre-shaped stainless-steel strips (0.127 mm thick and 6.35 cm wide) form a cylinder with a diameter of 21.7 mm.

The third mechanism is the SA drive. It provides rotational control for the SA's over a 358 degree arc. The drive module consists of two angular contact ball bearings which are slewed against each other by two redundant direct-drive motors mounted, together with a single-speed and a multi-speed resolver, on common rings. The angular position of the shaft is measured by the single-speed windings of the resolver. The multi-speed resolver is used to produce the signal for commutation of the torque motor by the Solar-Array Drive Electronics. A brake system containing 12 brake pads, equally spaced around the circumference of the drive unit, locks the solar array in position whenever it is not slewing.

Each of the four solar array blankets (Fig. 3) is made up of five identical power generating sections, known as the Solar Panel Assemblies (SPA) and four Buffer Assemblies which act as mechanical interface to the deployment mechanism.

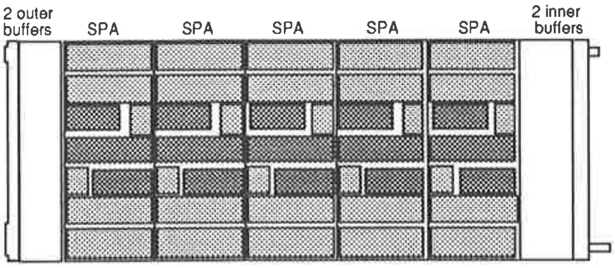

Figure 3: Solar-array blanket (2.4 m x 6.34 m)

Each of the power-generating SPAs are equipped with 3 solar cell strings, each having 106 solar cell assemblies (SCAs) in series, two of them with 8 single solar-cell rows in parallel and one of them with 7 single cell rows in parallel. The single cell rows for each string are connected via MoAg tapping bars in groups of 14, 15 or 16 cells. All of these groups are protected by flat solar cell shunt diodes for shadow protection. On the Inner Buffer Assembly (IBA), the individual solar cell strings are electrically connected by means of 75 micron thick silver foil strips to main and redundant connections for each SPA. They are routed to a flexible printed circuit board which serves as the interface to the harness attached to the deployment mechanism.
The basic carrier substrate of the flexible blankets consists of a 210 μm thick atomic oxygen (ATOX) resistant glass fibre/Kapton compound (Fig 4).

The power is provided by 48760 solar cell assemblies (SCAs, for details see table 1 and figure 5). They are bonded with silicone adhesive RTV-S 691 to the 20 SPA substrates. The thickness of the blanket compound including SCAs is 0.7 mm.

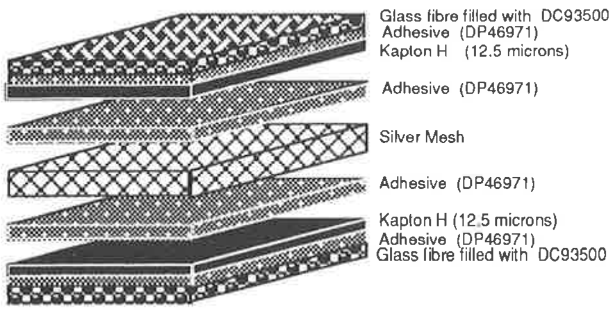

Figure 4: Exploded view of the 0.21 mm-thick, flexible carrier substrate of the solar-panel assemblies (SPA), including 50 micron-thick silver mesh for power transfer

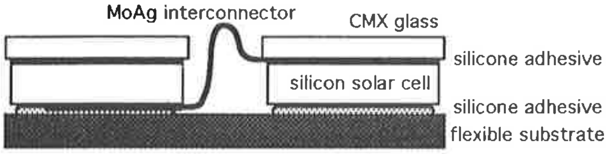

Figure 5: Interconnected solar cell assembly (SCA)

Base material	- Crucible crown silicon
Base resistivity	- 10 Ohm cm
Junction	- n-on-p shallow diffused
Back surface field	- p+ doping
Back side reflector	- Aluminium layer
Contact system	- Ti(Pd)Ag
Anti reflective layer	- TiOx
Surface roughness	- ≤1.5 microns
Silicon thickness	- 250 microns
Dimensions (solar cell)	- 20.8 mm x 40.2 mm
BOL SCA efficiency	- 14% (1AMO, 25°C)
SCA absorptivity	- 0.75 (unloaded)
SCA emissivity	- 0.83 (hemispherical)
Cover slide material	- Soft Boro-silicate base glass (CMX)
Antireflective layer (cover)	- MgF_2 (single layer)
Adhesive for cell bonding	Silicon, DC93500 + Primer
Dimensions (cover)	- 21.0 mm x 40.5 mm
Cover slide thickness	- 150 microns

Table 1: Solar cell assembly (SCA) characteristics

3. Post-flight investigation programme

It is of great importance to the Agency to study this generator in great detail after retrieval. It will help to improve future solar arrays for both the rigid panel concepts and flexible arrays resulting in more reliable design and better protected against damaging effects like random failures (e.g. short/open circuits) etc. The in-orbit performance of future arrays will be more predictable, the predictions more reliable and consequently the SA's can be designed and operated more cost effectively.

As a result of intense discussions among ESA experts and industry a post-retrieval investigation programme has been defined.

The programme plans for investigating all solar array components and mechanisms. Extremely valuable and reliable information on numerous essential subjects, like ATOX, meteoroid and space debris environment resulting damage, thermal fatigue and material degradation, etc. are expected.

The STSA-PFLIP has been split into 5 phases:

Phase 1:	Programme preparation and activities prior to arrival of solar-array wings in Europe
Phase 2:	Baseline programme
Phase 3:	Investigation of mechanisms
Phase 4:	Meteoroid and space debris investigations
Phase 5:	Storage of hardware

Pre-tests using ground based facilities and preliminary analyses have been performed to optimise the scientific output of the programme.

A great advantage to the STSA-PFLIP is the fact that in May 1993 the EURECA spacecraft is being retrieved and brought back to earth after about 9 months in a ≈500 km low earth orbit. A EURECA-PFLIP is being carried out on the two solar array wings. The experience gained during this programme and first results from EURECA-PFLIP will further help to optimise the STSA-1 investigation programme.

Compared to EURECA, STSA-1 investigations have the advantage that sufficient hardware can be provided for tests and investigation because there are no plans to re-use the first HST solar array. It is foreseen initially to completely disassemble and study the mechanisms of only one wing. All blanket buffers and at least one SPA are planned to be completely dissected and analysed. The remaining parts will be subject to specific examination with small areas being cut as required.

A separate paper on the EURECA-PFLIP will also be presented during this conference. There will be a smooth transition between the EURECA and STSA-1 PFLIP and with the exception of different main contractors being involved in the two programmes the solar array investigation will be carried out by the same team.

The STSA-PFLIP will be coordinated and managed by ESTEC. The investigation team for the STSA-PFLIP consists of all parties who were also involved in the development and manufacturing of the solar arrays, i.e: ESA/ESTEC, BAE, Dornier and DASA Wedel (formerly AEG). They have the expertise for disassembly of the parts they have developed, minimising the risk that evidence is destroyed when handling or investigating the hardware. Where required, institutes and universities (i.e. for meteoroid and debris investigations) as well as our European Space Tribology Laboratory (ESTL) will be involved in the investigations and evaluations of the flight hardware. Most of the material investigations are planned to be done in the ESTEC material division.

The key guidelines of this PFLIP are to ensure that no evidence is destroyed during SA shipping, storage and handling, or when samples are being removed.

3. 1. Programme preparation and activities prior to arrival of solar-array wings in Europe

During phase 1 of the programme the planned activities are still in the process of refinement. As already mentioned above, the intention is to involve as much as possible the same team members for both PFLIPs and transfer the experience gained from EURECA-PFLIP to the STSA-1 investigation programme. This provides the optimum conditions for the final preparation and planning of the programme. The investigating team members will be very well prepared for their investigations, this being the best basis for a successful STSA-PFLIP.

The first activities in the programme are the in-orbit inspections. Great emphasis will be given to the photographic and video coverage during HST approach, docking and in-orbit SA changeout. This will cover all SA areas and special close-ups of SA-highlights. Stereoscopic pictures are to be taken of all important parts and relative positions of moving parts (e.g. compensator rails, blanket alignment, etc.).

A similar intensive photographic coverage will be carried out after shuttle landing covering first inspections, also including insulation tests and continuity checks. Special attention will be given to the relative position of moving parts and other highlights.

In some areas LDEF-sample investigations suffered from post-flight contamination which hindered the investigations. For STSA-PFLIP it is planned that at the earliest possibility at KSC samples will be cut from the rolled-up solar array wings sealed in dry nitrogen and hand-carried to Europe for tests and investigations.

Samples are planned to be removed from the small deployed portion of the blankets, from the cushion and the thermal protection. These samples will be used also as reference for samples being cut at a later stage in the investigation programme.

There are no plans to disassemble any parts in the USA. The solar arrays will be sent, still mounted on the solar array carrier, to NASA-GSFC, where the SA's are removed from the carrier, packed and immediately shipped to ESTEC.

3. 2 Baseline programme

The second phase and main investigation programme starts with a detailed incoming inspection at ESTEC with photographic recording. The objective is to study changes of material properties and effects having a direct influence on SA power generation.
After a continuity and insulation check the blankets will be mechanically disconnected from the SDM and deployed. An absolute electrical performance test will be done using a Large Area Pulsed Sun Simulator (LAPSS). About three weeks after arrival in ESTEC front and rear side of the first two blankets will be available for detailed inspections.

3. 2.1 Environmental interaction effects and change of material properties

Silicon adhesive has largely been used for the blanket protection against ATOX. Those protective layers will experience changes in their material properties and their thermo optical characteristic. This is caused by the radiation environment including UV radiation, thermal cycling and attack by ATOX. Corresponding material investigations will study these type of synergistic effects.
Due to the low operation solar-cell string voltage of 37 volts (≈ 100 volts in Voc) plasma interaction or plasma sputtering is not expected to have an influence on the solar array hardware, but nevertheless it will be checked.

It is of interest to check the RTV adhesives for surface hardening and embrittlement, including depth effects, and to which degree the polymerisation chains have been changed, and also if changes caused the unbonding of the glass-fibre cloth from the Kapton foil.

As may be seen from the design description STSA has identical carrier substrate surfaces on the front and rear side of the flexible blankets. Since the solar cell side was always sun oriented, the effect of the contribution of UV radiation to the synergistic environmental effects can be evaluated.

UV radiation also tends to cause darkening or reduction in transparency of the transparent silicone adhesives if they are not shielded. RTV S-691 is used for gluing the cover slides to the solar cells and a darkened adhesive will reduce the power generation. One important question is, did the CMX cover glass sufficiently shield the adhesive from UV radiation?

How well the MoAg interconnector and its interconnection to the silicon cells withstood the aggressive environment will be investigated. Are they showing signs of thermal fatigue and how did the silver erode in the ATOX environment?
The molybdenum core of the interconnector is coated with 5 microns of silver via a platinum buffer layer to allow welding to the solar cell contacts on the front and rear of the cell.

At the time of retrieval the HST solar-array will have been exposed to more than 20.000 thermal cycles of between about +80°C and about -100°C during its time in low earth orbit. This thermal environment has induced maximum stress to the solar cell interconnectors and the welding joints on cell contacts. The effects on interconnectors and welding joints are quite different in nature and must be separately analysed.

i) The stresses induced to welding joints on solar cell n- and p-contacts are volume stresses created by the different materials welded together, i.e. by silicon, silver and/or molybdenum.

ii) The stress on solar cell interconnectors is imposed by the thermal movement of the individual components. The different coefficient of thermal expansion leads to a cell/cell-gap variation and thus cyclic stressing of the interconnector stress relief loop.

The ≈20000 thermal cycles seen by the interconnectors are in a representative range to permit study of these thermal cycle fatigue phenomena.

Some areas of the interconnector are exposed to the ATOX environment (Fig. 5) and have been attacked. How shielded areas (e.g. inside stress relief loop) compare with the surfaces exposed to the ram direction of the ATOX flux., and how the thermal movement of the interconnector influences the silver erosion are important questions to be answered. The clamped and embedded parts of the interconnectors (e.g. between cover slide and cell) will allow the study of possible creep erosion effects.

3.2.2 Verification of in-orbit failures

During its in-orbit operation the solar arrays experienced several anomalies (events) which are of interest and will be investigated in detail.

During solar array deployment it was detected that two solar cell strings in the +CC SPA (for location see fig. 1) were not generating power and later verified as open circuits from which one fully recovered one month later.

In the years 1991 and 1992 two short circuits were seen between power channels and telemetry circuits and one within one solar cell string reducing the effective string length from 106 cells to about 90.

The HST monitoring system does not allow clear identification of individual solar cell failures (open/short circuits).

All non electrical anomalies (e.g. tension sensor failure, SA jitter and stick-slip effects) which were observed until now are described in ref. 4.

Knowing that the SA's are planned to be brought back to earth all anomalies (expected and unexpected anomalies) were monitored very carefully and investigated in detail. This is essential for the post-retrieval activities to fully understand the origin of the anomalies. Some anomalies change their pattern, disappear with the time, are difficult to find after retrieval or are only observable in orbit. For example one open circuited solar array string fully recovered, one short circuit changed its resistance and one short circuit disappeared a few months after occurrence.

3.2.3 Power degradation studies

For all satellites, reliable solar-array power degradation studies are needed, and it is important that all damaging mechanisms are considered in the power profile predictions. The goal is to fully understand these power degradation effects. This give us the chance to minimise their effects on the solar array during the design phase, or even eliminate them in some cases.

For this reason great emphasis will be put in studying all negative effects on electrical power generation. Extensive radiation studies and tests will be performed to predict the total accumulated fluence and evaluate the effects of electron, proton and photon radiation on the solar-cell assemblies.

The most interesting parameters for the Space Telescope cell type, in combination with the 150 micron thick cover and resulting degradation characteristic for 1MeV electrons/cm2 is shown in figure 6.

These are well known and well established characteristics for solar cells radiated with 1MeV electrons. The radiation environment is also well known, but the uncertainty is, if the proton and electron spectrum is correctly converted to the 1MeV electrons. Ground tests for comparison will be done refining the predictions and power verification methods for future solar arrays.

YEARS	Isc	Voc	Pmax	Vmax	Imax	I(350)	fluence
0	0.33317	0.60480	0.15409	0.50500	0.30513	0.33217	BOL
1	0.32930	0.59330	0.14911	0.49540	0.30099	0.32802	8.480e+12
2	0.32644	0.58480	0.14554	0.48834	0.29803	0.32470	1.589e+13
3	0.32417	0.57950	0.14329	0.48390	0.29611	0.32220	2.222e+13
4	0.32261	0.57580	0.14181	0.48080	0.29494	0.32071	2.748e+13
5	0.32141	0.57340	0.14075	0.47870	0.29402	0.31965	3.166e+13

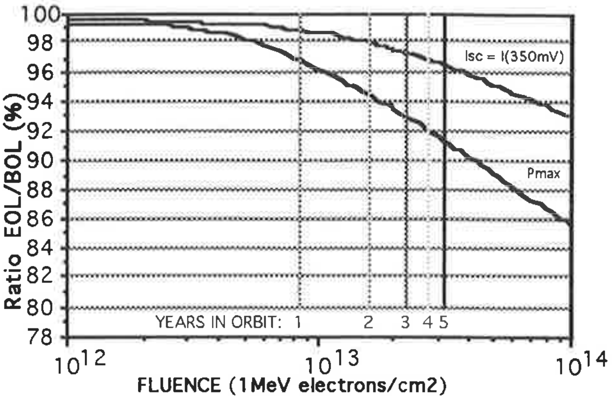

Figure 6. Solar cell degradation characteristic

When, solely the effects of radiation are used to evaluate the power during lifetime the resulting total degradation would be under-estimated.

The monitoring of in-flight generated power at the operation voltage does not allow to differentiate between power degradation caused by radiation and other damaging effects. Thus only a total power reduction is observed.

The solar cell efficiency also changes with the solar cell operation temperature. Parameters which alter the array temperatures are the cell efficiency itself and the thermo optical properties of the materials used on the outer surfaces of the array (see 3.2.1).

Years in Orbit	BOL	1	2	3	4	5
Calibr. Error	.980	.980	.980	.980	.980	.980
SCA mis-match	1.00	.998	.996	.994	.992	.990
Sun Intensity	.988	.988	.988	.988	.988	.988
Orientation Error	.996	.996	996	.996	.996	.996
Random Failure	1.00	.982	.970	.960	.950	.940
Micro-meteoroid	1.00	.995	.990	.985	.980	.975
Total	**.965**	**.940**	**.922**	**.906**	**.891**	**.875**

Table 2: Current or amperage loss factors for SA-deployment on 25th Apr. 1990

In addition to the natural environment (radiation temperature, ATOX) further potential impacts on the power output have to be considered. These are solar cell orientation errors, solar cell mismatch, meteoroid and space debris bombardment and random failures, which include open circuits as well as short circuits (not caused by meteoroid and space debris). These effects are considered in the form of current and voltage loss factors applied to the solar cell network. Except for the sun intensity the individual current or amperage loss factors typically considered were based on ground tests and best engineering estimate, but worst case and never expected to occur. Those used for the HST solar generator are summarised in table 2.

The evaluation of in-flight data from various satellites showed that for worst case predictions the solar array design engineer can rely on the total of the loss factors. The power profile prediction and actual in-flight data are given in figure 7. For operational reasons in the power conditioning unit, one of the 20 SPAs has been switched to open circuit. After 3 years in orbit in-flight data give between about 5 to 6% (depending on the sun calibration standard used) above the prediction.

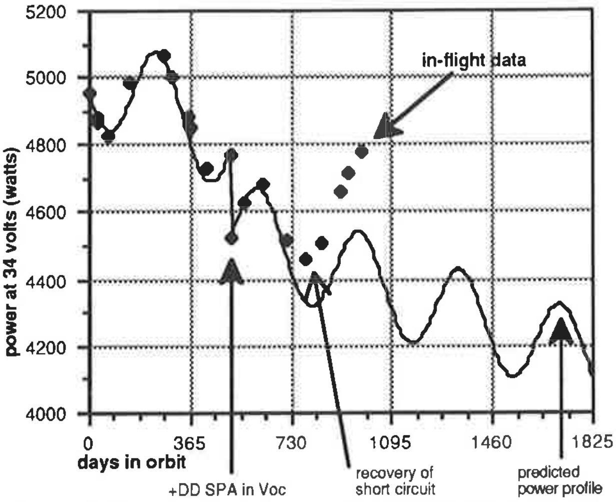

Figure 7: Predicted and actual in-flight power profile (JPL standard) of first set of HST solar -array

It is getting increasingly important for economical reasons to adjust these worst case factors, which normally cover all solar array eventualities, to change these losses to more realistic degradation factors. STSA-1 offers us the possibility to investigate which losses were considered too pessimistic or too optimistic, or may be there are others to be considered in the future.
For example, the effect of particle impacts on the power generation can be checked by a laser scanning the surface of the SCA. The distribution and number of impacting particles can be provided by the corresponding numerical models.
A darkening of cover slide adhesive by UV, if any, could be verified by means of spectral response measurements.

3.3. Investigation of mechanisms

The first activities in this field are the inspection of the spreader bar and the relative position of the rollers on the compensator rail and its function. These activities are foreseen to be carried out in USA, supported by in-orbit photographs.

At a later stage it will be checked if the MoS_2 coating is still on the rail, if there is evidence of wear, jamming or ATOX erosion. Forces to move the rollers will be studied and the investigations on the metal tape and spring inside the spreader bar will help to find the cause of the anomalous readings of the blanket tension sensor located in the spreader bar.

After completion of the first checks in ESTEC (electrical health checks, X-ray exposures and detailed visual inspection) the +wing is planned to be shipped to BAE, Bristol for a SDM deployment and retraction test on the water table (see ref. 3). During the movement the motor currents will be recorded and compared with pre-launch data. Other interesting parameters to be monitored are the desynchonization of the booms, blanket tension, function of micro-switches and electrical continuity of the solar cell strings. The deployed bi-stem booms will be checked for surface conditions (incl. thermo optical data), marks, deformations and particle impacts.

In general all moving parts will checked for evidence of wear and damage. Torques will be measured where applicable.

All three mechanisms (PDM, SDM, SAD) will be dismounted for detailed inspection and investigations.

The state of lubricant in each bearing will be assessed. Fluid reservoirs and possible fluid creep will be examined as well as surface treatments. Wavy washers/preload devices will be checked for deformation, adhesion etc.

Gears will be investigated for state of lubricant gear wear and wear of ceramic gear carriers.

Static adhesion or fretting will be examined on all clamps/end stops.

Electrical contacts will be checked. Motor currents including speed/torque characteristic will be studied as well as brushes and commutator surfaces.

The above list is not exhaustive but reflects to which detail we intend to study the mechanisms.
Most of the activities on components are planned to be performed at ESTL.

3. 4. Meteoroid and space debris investigations

The main aim for this investigation is to improve the existing meteoroid and debris flux models and to asses the degree of damage of impacting particles.

After an exposure time of nearly 4 years in orbit about 70000 particles greater than 10 microns are expected on the ≈130 m^2 (counting both sides of the array) from which several hundred will penetrate the blankets. The preliminary numerical impact analysis also indicated that there is no risk of critical damage, which would not allow a safe retrieval of STSA-1.

Figure 8 shows the impact crater of a 200 micron glass particle (≈5 km/sec) on the bi-stem boom. The double wall of the bi-stem boom is penetrated when a steel particle of 200 micron at 5 km/sec is used (Fig. 9).

It is foreseen to examine all solar array units for highlights and use only the four blankets (still ≈130 m^2) for the systematic documentation of crater and impacting particles. Based on the high number of impacts the plan is to document on the 4 blankets impact features ≥100 microns only. The cataloguing and investigation of smaller particles will be limited to one SPA (≈5 m^2) and one buffer assembly (≈3 m^2). As already mentioned, we will not exclude special highlights and the thermal covers on the mechanisms.

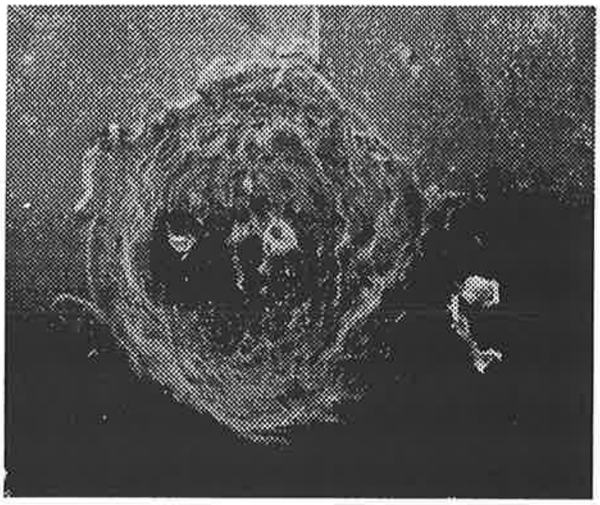

Figure 8: Impact crater of a 200 μm glass sphere on the bi-stem booms (≈5 km/sec, scale: 1cm= 100μm)

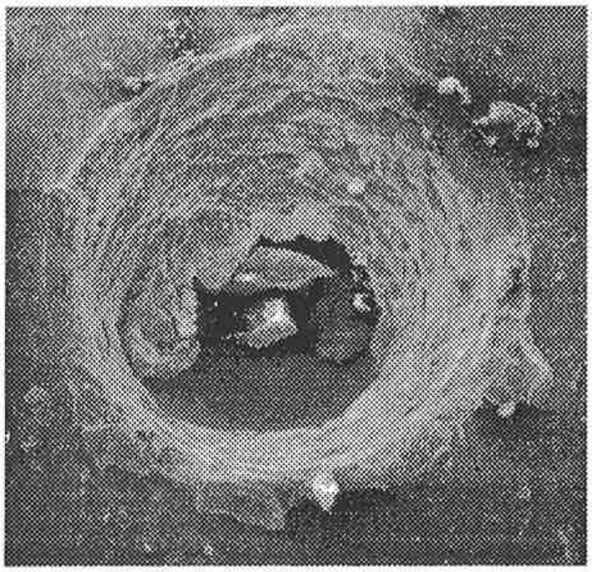

Figure 9: Penetration of one bi-stem boom double wall by a 200 micron steel sphere at a speed of ≈5 km/sec (scale: 1cm= 100μm)

With some luck we may find a sufficient number of trapped particles allowing us to perform a chemical analyses in order to distinguish meteoroids from man-made objects, with a statistically significant distribution.

Through dedicated in-situ experiments on spare material calibration measurements can be performed to study crater size versus particle size etc.

A major goal of this investigation is to study which size of craters have an influence on the power generation caused by particles hitting the SCA surfaces. Also which kind of particles cause short circuits between the electrical network on front of the blankets and the embedded silver layer in the carrier substrate or trigger some other failure mechanism.

All results will also be compared with the EURECA findings.

3. 5. Storage of hardware

Due to possible shortage of funds one or other activity may have to be postponed and parts will be prepared for safe storage. However, this will only affect some parts of the mechanisms.

In general, all hardware which has not been used for destructive testing will be sealed in dry nitrogen for storage for possible later usage, either to support some micro satellites with a small generator unit, for further investigations or anything else useful.

5. Schedule of PFLIP

With the actual shuttle launch date for the servicing mission on 2 December 1993, we foresee in our planning the arrival of the SA's in ESTEC in March 1994. This includes some margin. There is always the possibility that a launch is delayed. It is expected that, except for some meteoroid / debris particle investigations, the STSA post flight activities are completed mid 1995.

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