N95- 20506

EUROPE'S SPACE PHOTOVOLTAICS PROGRAMME

Klaus P. Bogus
European Space Agency
Noordwijk, The Netherlands

SUMMARY

The current space PV technology development programme of ESA is described. The programme is closely coupled to the European space mission scenario for the next 10 year period and has as main objective to make the most effective use of the limited resources available for technology in the present economical climate. This requires a well-balanced approach between concentration on very few options and keeping the competition alive if more than one promising technology exists.
The paper describes ESA's main activities in the areas of solar array technology, solar cell technology,solar cell assembly technology, and special test and verification activities including the in-orbit demonstration of new technologies.

INTRODUCTION

Europe has had a very successful record in the field of space photovoltaics and has achieved a competitive position in the world market. For a large variety of European spacecraft systems photovoltaic solar generators are the exclusive source of electrical power and additionally, Europe has succeeded in exporting solar arrays across the Atlantic (e.g. IUE, Hubble Space Telescope, CTS-Hermes and INTELSAT).
The main purpose of the space photovoltaic technology development programme is to maintain the high standard of European solar array technology by carefully modernising the existing concepts in a step-wise approach. The smooth introduction of new technologies into flight programmes is achieved by close cooperation between technologists and project engineers.
The close coupling of the technology programme to the European mission scenario for the next 10 years is perfectly in line with the approach described above and leads to a fast application cycle of new technologies. A disadvantage of this approach is the resulting low priority for globally attractive new technologies which are not directly required in the ESA mission scenario with it's limited scope.

DETAILS OF ESA'S SPACE PV TECHNOLOGY PROGRAMME

The programme is described in the 7 tables below according to a systematic division into solar array technology, solar cell technology, assembly technology, technology verification activities and supplementary activities.
The first column of each table contains the technology activity title, the second column indicates the present status of the activity. "Proposed" stands for a new activity which is not yet accepted in the budget planning, after acceptance it turns into "planned" , and after initiation into "running". The 3rd column identifies the frame-programme unter which the activity is funded: "Basic" is the general basic TRP(Technological Research Programme) of ESA, "ASTP" is the acronym for applied supporting technology programmes of the Telecommunications satellite area and "GSTP" is the newly introduced general supporting technology programme of ESTEC for all ESA missions. Additionally, several of the national activities in the ESA-member states are harmonised with ESA and run under common management arrrangements. Schedule indications can be found in the 4th column. The last column contains summary descriptions.

SOLAR ARRAY TECHNOLOGY.

ESA's Solar Array Technology is based on a two main design concepts: Advanced lightweight rigid panel arrays and advanced flexible blanket arrays. With both concepts a high degree of maturity and flight experience has been accumulated in recent flight programmes: OLYMPUS-1, HST and ERS-1

are operating very successfully with flexible blanket arrays, whereas EURECA, HIPPARCOS and the ECS/MARECS satellites are supplied with rigid panel arrays.
The solar array technology development aims at the improvement of the present lightweigth carbon-fibre face-sheet panels for specific future telecom-missions . Since the technology requirements are generally very mission specific it has become general practice do do these developments within the corresponding flight programmes and not in generic technology programmes.
Unfortunately EUROPE has presently no new programme requiring flexible blanket solar arrays so that this technology which has already reached a high degree of maturity, can not be further improved.
The development of alternative concepts was limited to studies on concentrator arrays (SARA-Louvre, Holographic Dispersive).

SOLAR CELL TECHNOLOGY.

This part of the programme comprises two main elements: Improvement of silicon solar cells and development of GaAs solar cells:
- Hi-ETA silicon cells with 16-17% efficiency have been pre-developed and are now approaching the pilotline production stage.
- Further improvement towards 18% efficiency are under pre-development using advanced passivation and optical confinement
-a demonstration of a 20% efficiency silicon cell is foreseen in a basic R&D study on small area, low quantity samples
-GaAs and GaAs-on-Ge cells have been pre-developed in Italy, Great-Britain and Germany.
-The next step will be a pilotline production of GaAs-on-Ge cells
- Further improvements of III-V-compound cells are expected in the area of ultra-thin (superstrate supported) GaAs cells and multi-junction/tandem cells.

SOLAR CELL ASSEMBLY TECHNOLOGY.

This part of the Programme covers :
- the development of improved Aluminium solar cell interconnectors (ATOX-resistant, low-cost)
- the development of ultrasonic welding for Si- and GaAs cells (long cycling life, low-cost)
- advanced cover-glass bonding (Direct Electrostatic bonding, Teflon Pre-preg bonding)
- Infra-red reflective coatings on cover-glasses (improved efficiency through lower Temp.)
- Development of integrated solar cell modules (GaAs-thin film and Silicon superstrate concepts).

TECHNOLOGY VERIFICATION TESTS.

Apart from the activities performed at SPASOLAB (ESA's solar cell laboratory in Madrid), the main activities are related to the investigation of space environmental effects on solar arrays. This includes investigation of synergistic effects, thermal cycle induced fatigue, plasma and atomic oxygen effects, micrometeorite impact effects and particle radiation damage in solar cells. Radiation damage investigations are required for two different reasons: One is the evaluation of new solar cells (e.g. advanced GaAs and Hi-ETA silicon cells), the other the planning of missions in different orbits (e.g. the new Telecom-missions in high-inclination, medium altitude orbots with equivalent fluences of more than10E16 One-Mev-electrons /sqcm).

SUPPLEMENTARY ACTIVITIES.

This segment contains mainly the preparation and evaluation of flight experiments and the Post-flight investigation programmes on the HST and EURECA solar arrays reported in another part of this conference.

SOLAR GENERATOR TECHNOLOGY PROGRAMME

1994 STATUS

1. ARRAY SYSTEM DEVELOPMENT
2. ASSEMBLY TECHNOLOGY
3. COMPONENT TECHNOLOGY
4. TECHNOLOGY VERIFICATION TESTS
5. SUPPLEMENTARY ACTIVITIES

SOLAR GENERATOR TECHNOLOGY PROGRAMME
1. ARRAY SYSTEM DEVELOPMENT

*	SOLAR ARRAY FOR HIGH POWER APPL.	RUNNING	ASTP-4 9	94-95	ADAPTATION OF RIGID ARRAYS TO 5-7kW TELECOM APPLICATIONS
*	ADVANCED RIGID PANEL ARRAYS	RUNNING	TELECOM HARMO	93-95	ARAFOM (FSS), HOTBIRD+ GSR(AS),MARK-3 (DASA)
*	LILP ARRAYS	RUNNING	BASIC 4	91-93	LOW POWER/LOW INTENSITY ARRAYS FOR MARSNET
*	SYSTEM ANALYSIS & ASSESSM. NOVEL CELLS	PLANNED	BASIC 9	95-96	EVALUATION OF NEW CELL TYPES ON ARRAY LEVEL

SOLAR GENERATOR TECHNOLOGY PROGRAMME
2. ASSEMBLY TECHNOLOGY

*	ALUMINIUM INTERCON. TECHNOLOGY	RUNNING	BASIC 6	87-94	DEVELOPM. OF ULTASONICALLY WELDED ALU-INTERCONNECTORS
*	SOLAR CELL ASSEMBL. TECHN. (SI & GaAs)	PROPOSED	ASTP-4 9	?	CONTINUE ASTP-3 DEVELOPM. FOR NEW CELL TYPES
*	INT. ELEV. VOLTAGE MODULE	RUNNING	BASIC 6	93-95	DEV. OF INTEGRATED GAAS ULTRATHIN MODULES WITH DIODES
*	I-R-REFLECTING COATING	RUNNING	ASTP-4 9	92-94	REDUCTION OF OPER. TEMPERATURE BY REFLECTOR ON COVER-GLASS
*	TEFLON-BONDING OF GLASS ON CELL	RUNNING	ASTP-4 9	92-94	TEFLON BONDED CELL-ASSEMBLIES WITH ESD-PROTECTION

SOLAR GENERATOR TECHNOLOGY PROGRAMME
3. COMPONENT TECHNOLOGY-A

*	ALTERNAT. SOLAR CELL ASSESSMENT	RUNNING	BASIC 9	89-94	EVALUATION OF "3RD GENERATION" CELLS FOR SPACE
*	GaAs-SOLAR-CELL DEVELOPMENT	RUNNING	ASTP-3 &HARMO	87-94	DEV. OF GaAS CELLS BY MOCVD ON GaAs AND GERMANIUM
*	LILT SOLAR CELLS	RUNNING	BASIC 4	91-95	DEV. OF CELLS WITH 25%-EFF. IN DEEP SPACE (ROSETTA)
*	THIN-FILM CELLS	RUNNING	ASTP-4	92-94	PRE-DEVELOPMENT OF CIS-CELLS; SYSTEM-ASSESSMENT

SOLAR GENERATOR TECHNOLOGY PROGRAMME
3. COMPONENT TECHNOLOGY-B

*	PILOTLINE HI-ETA SILICON CELLS	RUNNING	GSTP-1 9	94-96	END-DEVELOPMENT OF 16%-EFF. CELLS INCL. PILOT PROD.
*	ADVANCED LIGTHW. GAAS CELLS	PLANNED	GSTP-1 9	94-96	CASCADE/TANDEM CELLS;>22%, ULTRA-THIN
*	GE-SUBSTRATES FOR GAAS CELLS	RUNNING	GSTP-1 9	93-95	DEVELOP IMPROVED SUBSTRATES IN PILOTLINE

SOLAR GENERATOR TECHNOLOGY PROGRAMME
4. TECHNOLOGY VERIFICATION TESTS

*	S-A ENVIRONMENTAL INTERACTIONS	RUNNING	BASIC 6	93-94	IDENTIF. AND TEST OF SYNERGISTIC EFFECTS: MICROM./PROTONS/ATOX
*	ESD-TEST SIMULATION	RUNNING	BASIC	93	MODEL OF ESD INTERACTIONS OF S-A's ; REPR. TEST
*	SPASOLAB	RUNNING	BASIC	93-95	TYPE APPROVAL TESTS (PSS-01-604)
*	ARCHIMEDES	RUNNING	BASIC	94	p+ & e- TESTS OF NOVEL CELLS FOR MISSIONS WITH HIGH FLUX

SOLAR GENERATOR TECHNOLOGY PROGRAMME
5. SUPPLEMENTARY ACTIVITIES

*	FLIGHT EXPERIMENTS	RUNNING	TDP	94	IN-ORBT VERIFICATION OF NEW CELLS (STRV, HEALTHSAT,ETC.)
*	PORTABLE SUN SIMULATOR	RUNNING	GSTP-1	94-95	MINI-FLASHER FOR FIELD TESTS
*	EURECA SA	RUNNING	BASIC	93-94	POST-FLIGHT INVESTIGATIONS
*	HST SA-1	RUNNING	BASIC	94-95	POST-FLIGHT INVESTIGATIONS

SESSION I

InP CELL DEVELOPMENT