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Title

Stratospheric Flight of a Balloon-Borne Solar Cell Testing Facility

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Abstract

The vast majority of today's spacecraft power systems are based on photovoltaic energy conversion. Solar cell electrical characteristics are strongly influenced by the spectral composition of the received sunlight and by the thermal conditions they are exposed to. The characterization of the cells in a relevant environment in terms of both spectral irradiance and thermal conditions is of paramount importance in order to understand how they will behave in the actual operational environment. Solar cell manufacturers, in particular, need so-called "primary standard" cells to be characterized in AM0 (air-mass zero, i.e. the LEO environment) spectral conditions so to be used later for the calibration of secondary standards and, eventually, of experimental or production units. For cells intended for spacecraft use, the operational environment is not easily reproduced in ground facilities, as an accurate simulation of the solar light spectral features with artificial light sources is difficult and expensive.

Stratosphere, at about 20-30 km altitude, is a good approximation of the LEO environment in terms of spectral irradiance, thermal conditions and ambient pressure. Spectral irradiance at AM0 is appreciably different from sea-level, due to the lack of attenuation due to the various layers of the atmosphere, i.e. the ozone layer, and to the presence of suspended particles of water and dust. Since the 99% of the air mass is below the stratosphere limit, it can be said, with a good approximation, that the stratosphere environment is equivalent to AM0. The low background temperature, around -50 °C, and the lack of natural convection due to the low air pressure (about 10 mbar), result in strong temperature variations depending on exposure of the cell to direct irradiance from the Sun, just like in the LEO environment.

In order to provide a quick, affordable stratospheric cell characterization service, we designed a facility suitable for flying on sounding balloons. The main function of such a device is to characterize the performance of various types of solar cells in a stratospheric environment by means of determination of their characteristic IV and PV curves, focusing particularly on the assessment of closed-circuit current, open circuit voltage and point of maximum power, and finally correlating these characteristics with local irradiance and with the temperature of the cells themselves. The facility includes an exposed plate hosting a number of solar cells, dedicated current/voltage (IV) curve tracers, a temperature sensor for each cell and an irradiance sensor. The system is attached to a COTS helium-filled sounding balloon and flown up to the stratosphere through a 3-hour mission. During the ascending and floating phases of the flight, the IV curve of the cells under test is continuously recorded, so to allow for comparison of performance of the different photovoltaic technologies in identical, real stratospheric flight conditions, as well as to detect performance changes with external temperature, irradiance and altitude (as a result of the different spectral balance in sunlight).

In this paper, we present the design of the solar cell testing system and the main results of a flight test carried out in summer 2022, reaching a maximum altitude of 35 km. The test included three different solar cell technologies, providing a large number of I/V curves for various working conditions.

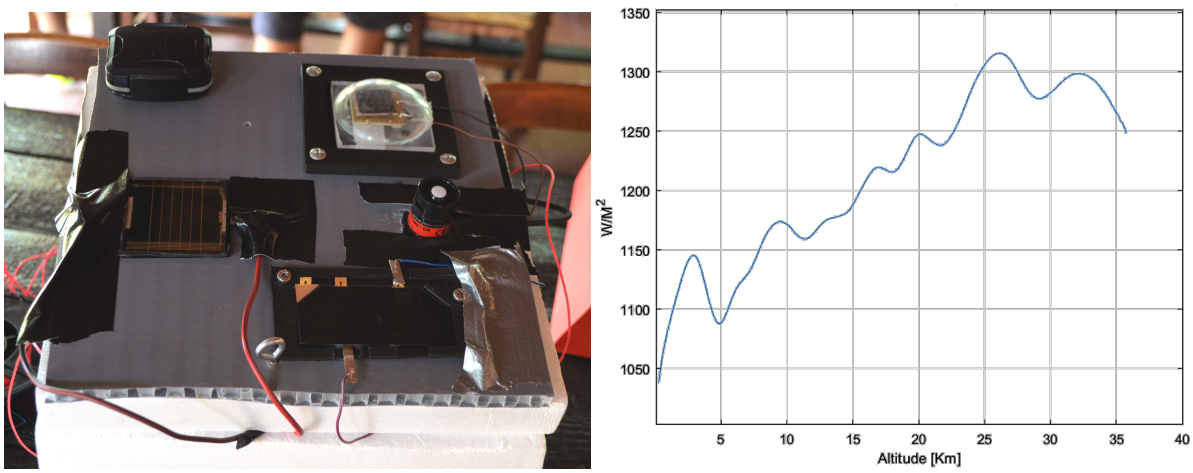

Fig. 1 - Left: the test facility ready for flight; right: measured irradiance vs. flight altitude.

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