5.3 In-situ manufacturing of thin-film spacecraft, landers and rovers

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Access to space has long been a bottleneck for space missions, whether commercial, scientific or educational. The time from mission concept to first data being received from a spacecraft in its intended orbit typically ranges from years (in low earth orbit) to decades (for interplanetary missions) due to a combination of programmatic, launch schedules and celestial mechanics. We have developed an alternative approach that potentially reduces this schedule to as little as hours per mission, by manufacturing thin-film spacecraft, landers and rovers in-situ.

The CubeSat revolution [1] has demonstrated that a wide range of space missions can be implemented in a restricted envelope (typically based around 0.25 to 6x multiples of 10x10x10cm/1.3kg units) if the benefits of lower costs and faster time to orbit are compelling enough. Space missions that might previously have been implemented with spacecraft with masses of the order of hundreds or even thousands of kilograms have been implemented as CubeSats and have successfully operated as far away as Mars. The standard CubeSat unit was chosen to be a one litre spacecraft with one watt of photovoltaic power if covered with standard space rated solar cells that could be designed, built and launched within the time constraints of a typical American Masters degree program. The authors have demonstrated that spacecraft with similar functionality to CubeSats can be designed and built in the laboratory at gram (printed circuit board based) [2] and milligram (thin-film printed spacecraft) [3] scales using manufacturing techniques that are compatible with the space environment in a matter of hours.

A spacecraft printer CubeSat has been designed that allows milligram scale thin-film printed spacecraft, landers or rovers to be designed on earth, transmitted to the spacecraft printer, whether in low earth orbit (<1s) or on the surface of Mars (<24 minutes), and printed in-situ. The CubeSat combines several additive manufacturing, finishing and testing processes in a single integrated device permitting fully functional self-contained spacecraft and other exploration platforms based on an up to 2500mm² polyimide substrate to be deployed. Proof of concept printed spacecraft and missions such as a Solar Weather Buoy and a Mars Meteorological Microlander integrating avionics, communications, instrumentation and power subsystems have been developed and tested in simulated space environments. On-orbit demonstrations of printed spacecraft and spacecraft printer are planned in 2020.

References

Figure 1. a) gram scale printed circuit board and b) milligram scale printed spacecraft