

## Valuing Exploitation of Moon Resources using Real Options

F. Piccolo, D'Appolonia SpA  
M.A. Perino, Thales Alenia Space SpA  
G. Borriello, Aviospace SpA  
C. Tuninetti, Rheinmetall SpA

Purpose of a successful and widely-accepted exploration programme should be not only advancement in planetary science but also development of terrestrial economy. Thus, use of space resources will be key in the development of an affordable exploration architecture.

Consumables and, in the longer term, propellants, will prove too costly if delivered from Earth, especially in case of the establishment of a surface base and of a permanent colonization of the Moon. Colonization will make a high level of autonomy for the crew somewhat mandatory. This makes an architecture based on cryogenic and "refuelable" propulsion a promising solution, in terms of projected profitability of investments in space.

A refuelable architecture would be also more appealing for private investments and tourism, lowering the transportation cost to the Moon and thus the average ticket for a futuristic tourism on the moon.

Investment strategies with high risks and uncertainty or irreversible corporate decisions coupled with managerial flexibility provide the best candidates for real options. Valuations of investments through real options were extremely hot during internet bubble, where the market environment was almost unknown. After the blast of the bubble, real options become a standard valuation method in a number of R&D-intensive industries, including oil and gas exploration and production, pharmaceutical research and development, e-commerce valuation, IT infrastructure investment, mergers and acquisitions.

And, last but not least, prioritization of venture capital investments that closely resemble prioritization of investments in space technologies.

Economic considerations on the exploitation of Moon resources and its impact on the architecture choices are developed using real-options calculations, and a comparison with the results achieved with traditional discounted cash-flow methods is presented.

### AUTHORS:

Fabio Piccolo is an aeronautical and aerospace engineer. He works since 1997 in the Space sector first affiliated to Vitrociset company, then to Aero Sekur, and now to D'Appolonia. He is author of more than 10 papers presented in Space Conferences (mainly ESA sponsored) and has been chairman of the Descent and Landing System session at Arcachon conference in 2006. Currently he is in charge of D'Appolonia participation to ESA Exploration Architecture studies.

M.A. Perino is responsible of Advanced Studies at Thales Alenia Space, Infrastructures and Space Transportation division. In the 1990's she led the studies that brought to the definition of current ESA AURORA programme and is a reference person in the establishment of International Space University. In the last two years she led Thales Alenia Space participation to ESA Exploration Architecture studies, being the one of the two reference industrial contacts for ESA and coordinator of one of the research teams.

G. Borriello, former Marketing Executive at Alenia Spazio, and specialist in the field of system design and space transportation, is one of the components of Board of Directors at Aviospace, a consulting companies providing engineering support services to private and institutional space customers. He has been the reference person in an ASI-sponsored study aimed at the design of a Moon lander and, throughout the last year, the program manager of Rheinmetall Italy participation to ESA Exploration Architecture studies.

C. Tuninetti, Head of Space Programs at Rheinmetall Italy, has been during 2007/08 the responsible of Rheinmetall Italy participation to ESA Exploration Architecture studies. He is also responsible of many other space programs at Rheinmetall, including participation to VEGA ground segment, FLECS inflatable module project and Miosat (small satellite ASI program).