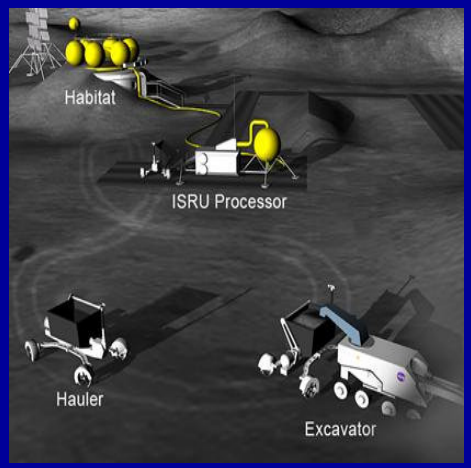
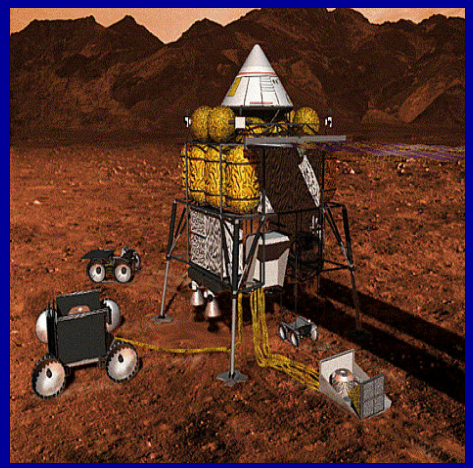
Development of novel ISRU and ISFR technologies for space exploration

G. Corrias, R. Licheri, A. Concas, R. Orrù, Massimo Pisu, G. Cao





Congresso Nazionale di Space Renaissance Italia, 8-9 Maggio 2014, Milano, Italy

ISRU: In-Situ Resources Utilization

- Technologies to extract consumables (O_2, H_2O, N_2) for human life-support replenishment and source material for ISFR

ISFR: In-Situ Fabrication and Repair

- Fabrication Technologies
- Repair and Non Destructive Evaluation Technologies
- Habitat Structures

Perspectives:

- Minimize the materials carried from Earth
- Reduce launch mass and cost
- Increase mission-time

Progetto COSMIC (2009 – 2013)

Ente finanziatore: ASI (500000 Euro)

Soggetti partecipanti pubblici:

UNICA-DICM (Dipartimento di Ingegneria Chimica e Materiali dell'Università di Cagliari)

CRS4 (Centro di Ricerche e Sviluppo e Studi Superiori in Sardegna)

DET-CNR (Dipartimento Energia e Trasporti del CNR)

ITIS (Ist. Tecnico Industriale Statale 'E. Fermi', Cosenza)

Soggetti partecipanti privati:

COREM Srl

SPACELAND Srl

MAIN OUTPUTS OBTAINED

Internazionale già concesso e nazionalizzato in 6 paesi

G. Cao, A. Concas, G. Corrias, R. Licheri, R. Orrù, M. Pisu, C. Zanotti «PROCEDIMENTO DI FABBRICAZIONE DI ELEMENTI PER STRUTTURE ABITATIVE E/O INDUSTRIALI SUL SUOLO LUNARE, MARZIANO E/O DI ASTEROIDE» 10453PTWO; Applicants ASI, UNICA; Luglio 2010.

(per realizzare strutture protettive nei riguardi di meteoriti e radiazioni cosmiche)

Internazionale già concesso e nazionalizzato in 6 paesi

G. Cao, A. Concas, G. Corrias, R. Licheri, R. Orrù, M. Pisu «PROCEDIMENTO PER L'OTTENIMENTO DI PRODOTTI UTILI AL SOSTENTAMENTO DI MISSIONI SPAZIALI SUL SUOLO MARZIANO MEDIANTE L'UTILIZZO DI RISORSE REPERIBILI IN SITU» 11205PTIT; Applicants ASI, CRS4, UNICA; Luglio 2011.

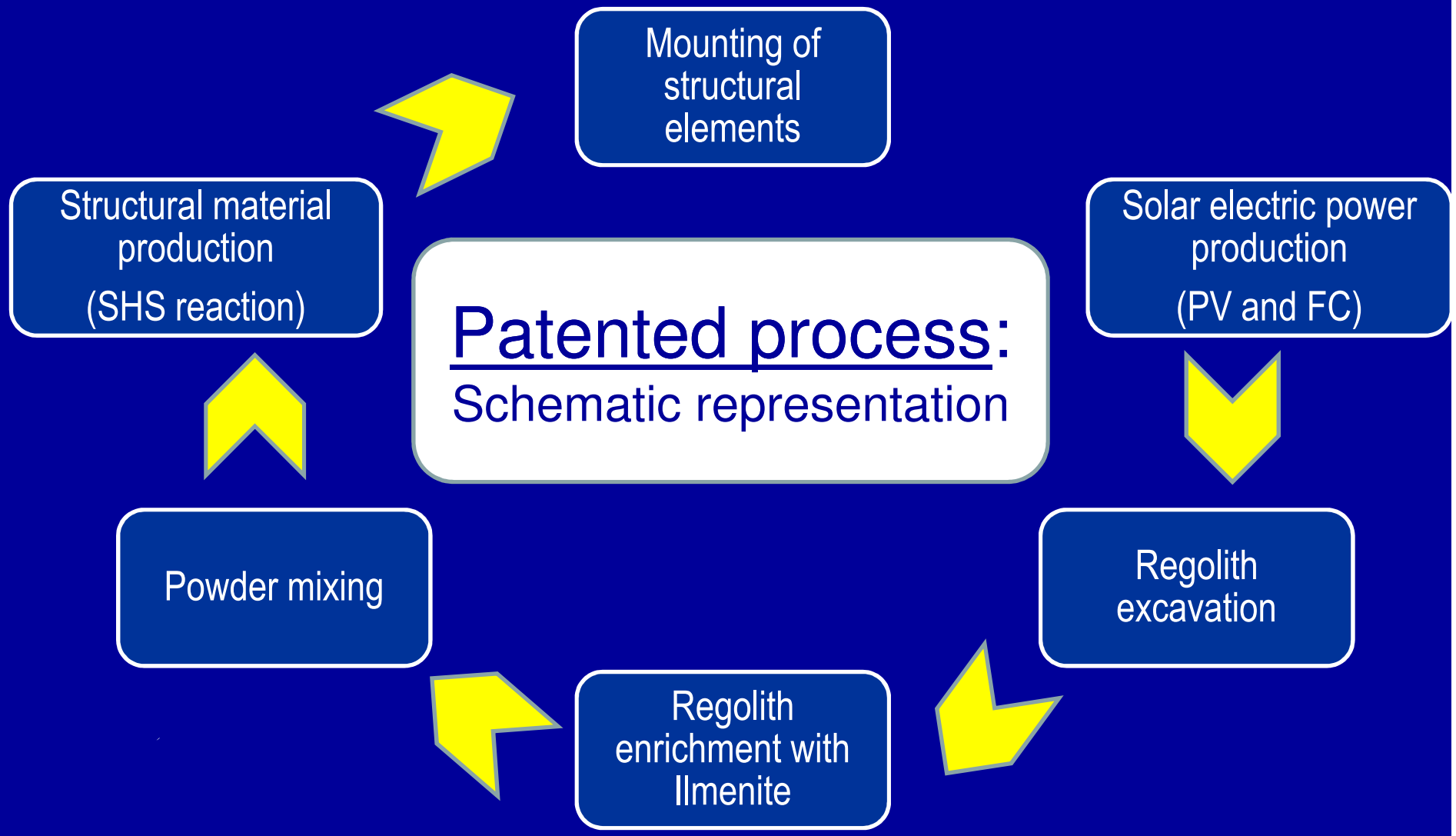
(per consentire il sostentamento di missioni umane su Marte)

Moon: overview

MOON	
Distance	*363104-405696 km*
Time required	*three days*
Gravity	*1/6 g*
Temperature	*-258 ÷ 127 °C*
Atmosphere	*10^{-12} torr*
Soil main minerals	*Ilmenite*
	Ca-rich Piroxene
	Plagioclase
	Anorthite

Cosmic rays and solar wind ⟶
fabrication processes for suitable protection structures

Fabrication of Lunar physical assets



Fabrication of physical assets: State of the Art

- The production of structural elements without taking advantage of in situ materials has been proposed ***Moore et al. International Journal of SHS, 14 (2005)***

- A certain geothermite reaction which did not display self-propagating character and required long time and large amount of energy to be ignited has been investigated ***Faierson et al., Acta Astronautica 67 (2010)***

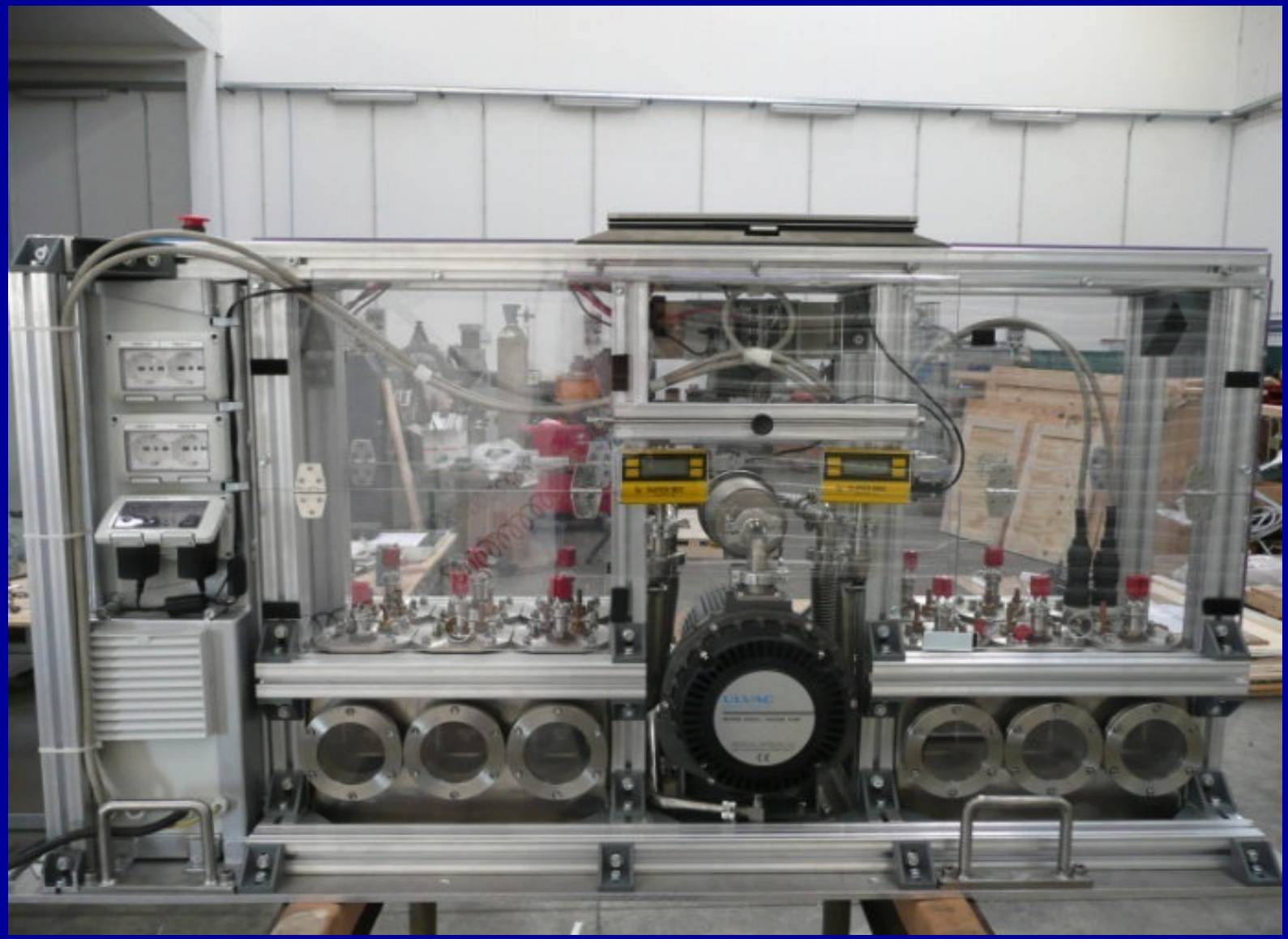
- Lunar regolith as diluent has been addressed ***Martirosyan, K. S. et al., 37th Lunar and Planetary Science Conference (2006)***

- The use of Magnesium as reducing agent has been analyzed without taking into account its high vapour pressure and the corresponding low boiling temperature in low pressure conditions ***White et al., 49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition (2011)***

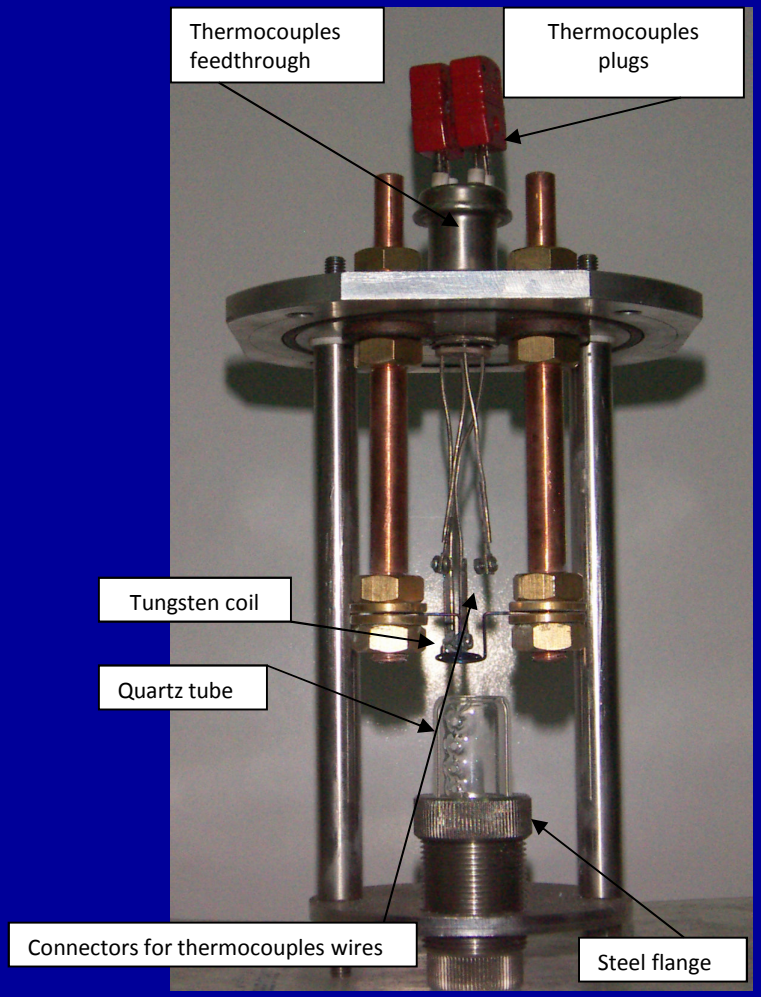
Lunar Regolith Simulant: JSC-1A

Mineral group	Chemical species
Ilmenite	($FeTiO_3$)
Plagioclase	Anorthite ($CaAl_2Si_2O_8$)
	Albite ($NaAlSi_3O_8$)
	Orthoclase ($KAlSi_3O_8$)
Olivine	Fosterite (Mg_2SiO_4)
Ca-Piroxene	Wollastonite ($CaSiO_3$)

Set-up for ground and parabolic flight experiments



Set-up for ground and parabolic flight experiments -2



NOVESPACE

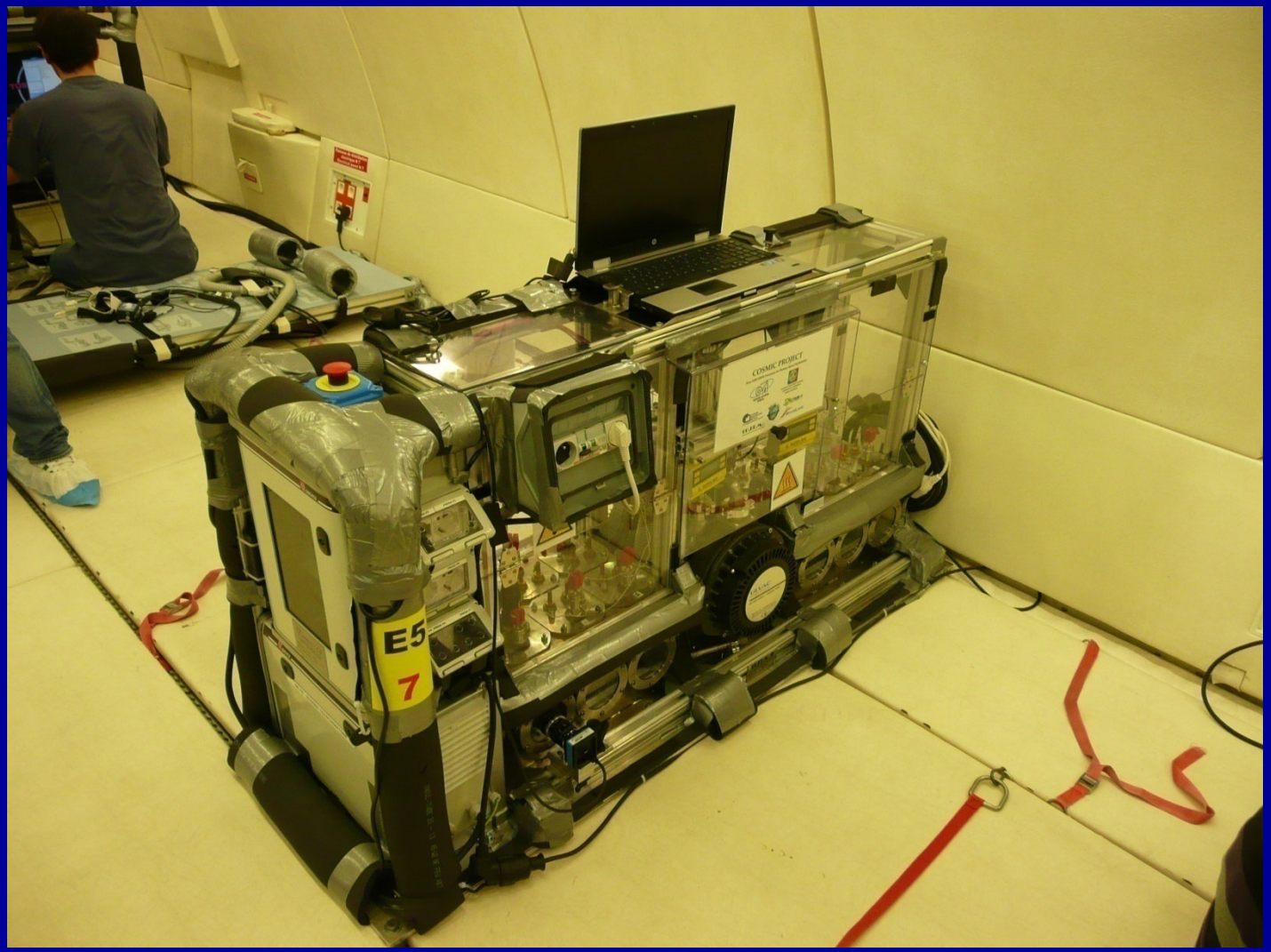
Ref: RG-2009-2
Revision date: April,7th 2009

NOVESPACE A300 ZERO-G RULES AND GUIDELINES

NOVESPACE
15, rue des Halles
75001 Paris – France

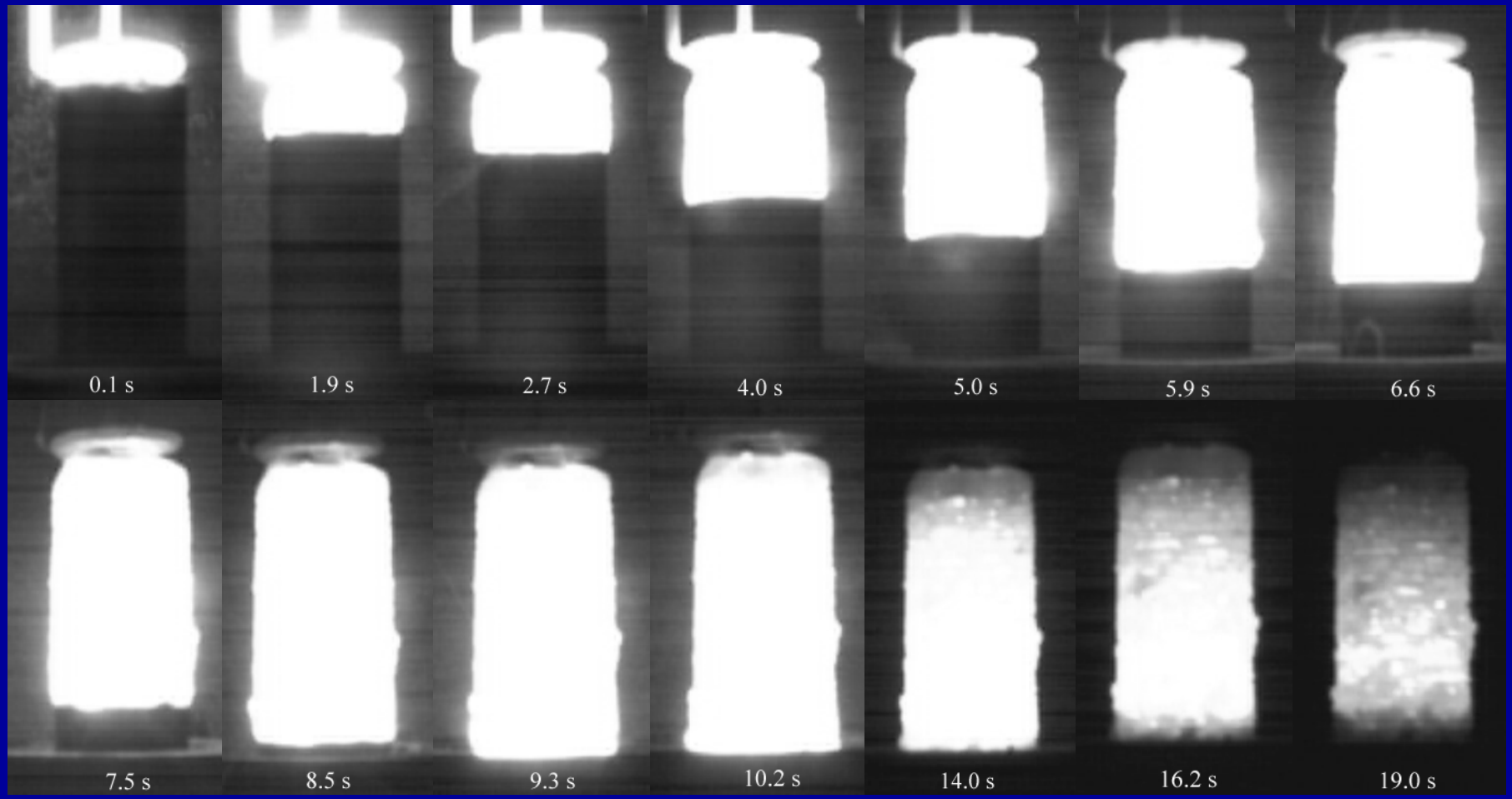
NOVESPACE
Rue Marcel Issartier
33700 Mérignac - France

Set-up in parabolic flight configuration



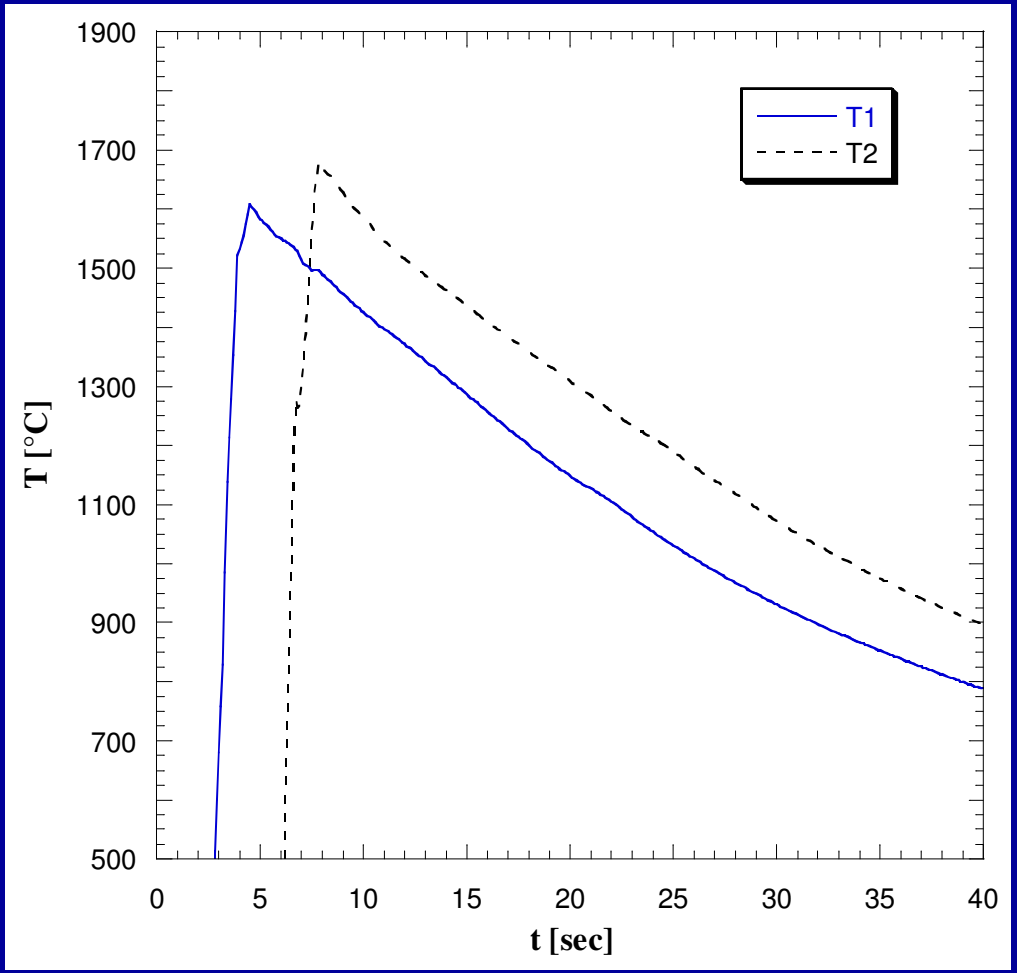
Production of physical assets

Video output showing the SHS process evolution



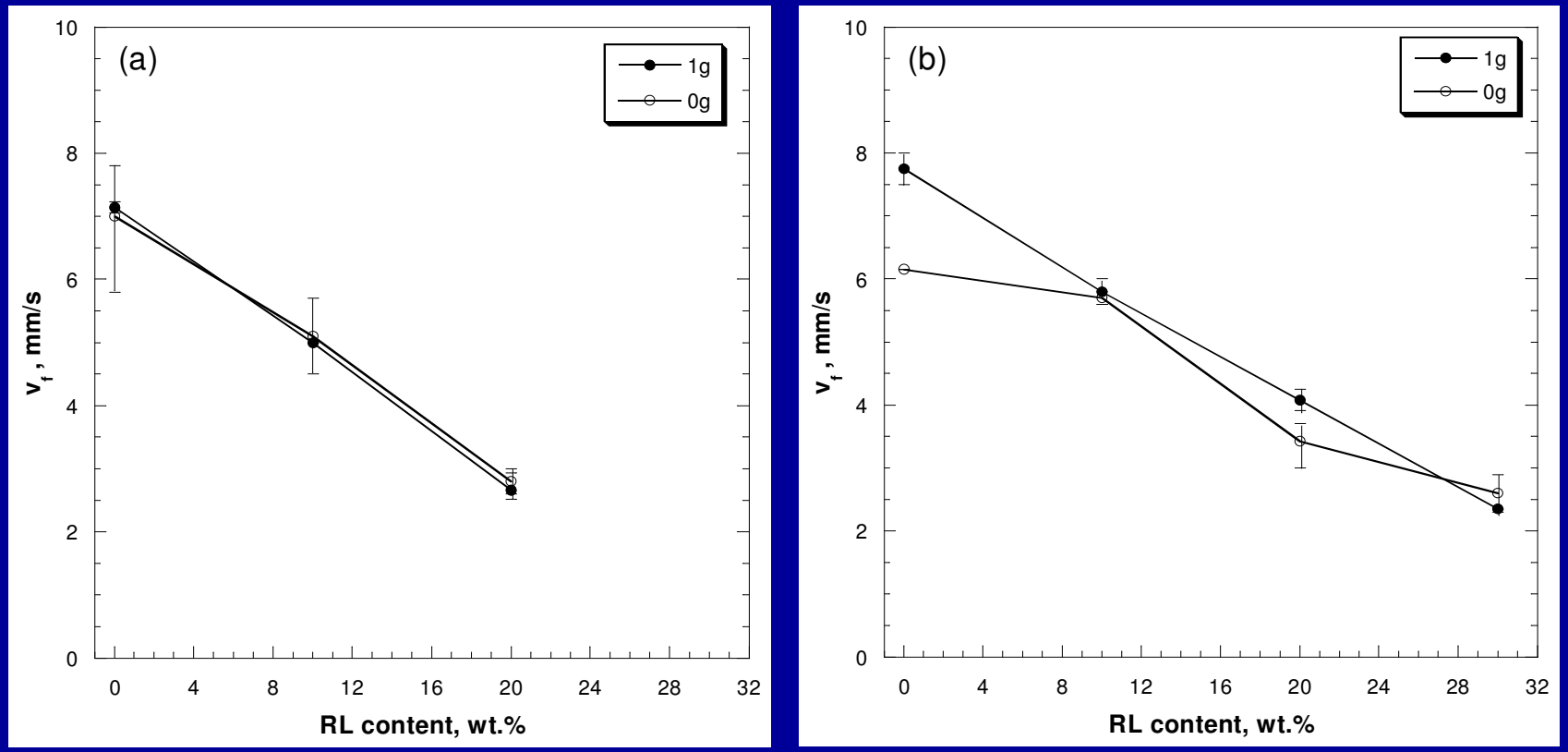
Temperature profiles

Temperature profiles recorded during the SHS process for the case of the S3_R_L30



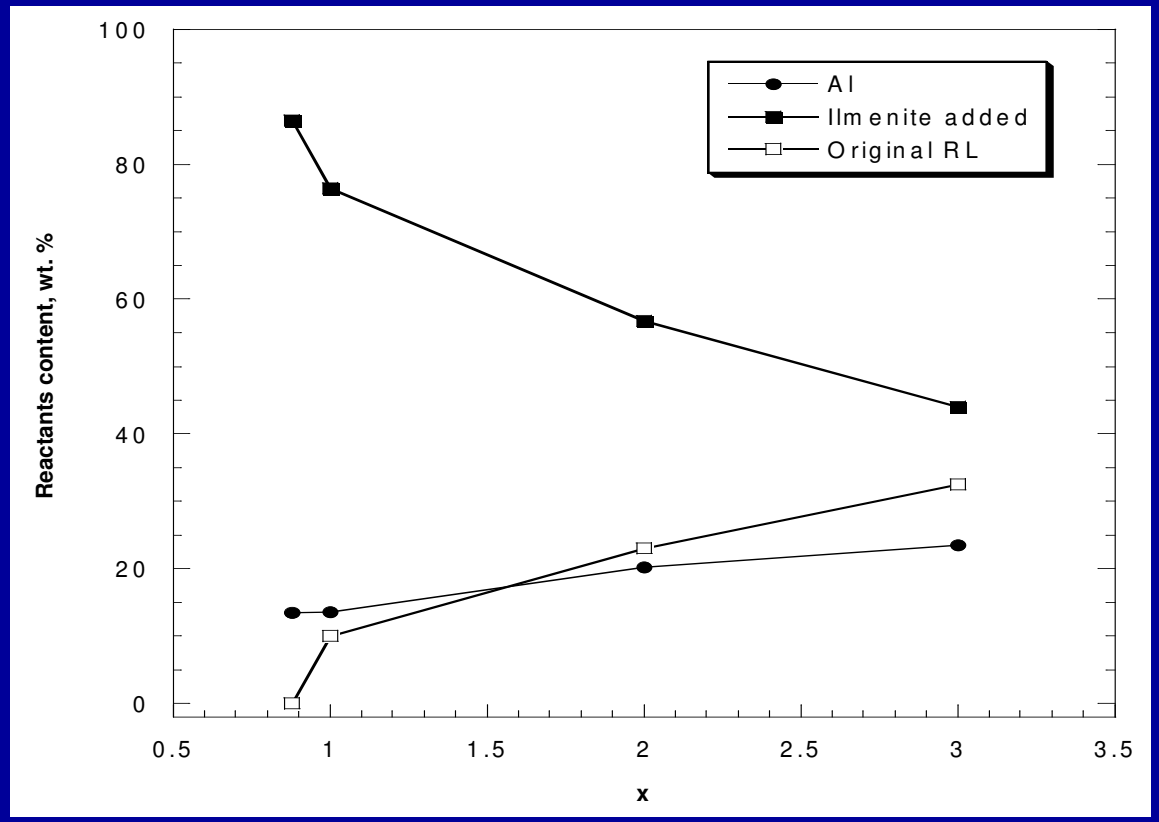
Gravity effect on front velocity

Effect of gravity level on the average velocity of the self-propagating combustion front for the cases of ($Al/FeTiO_3$) molar ratios equal to 2 (a) and 3 (b), respectively.



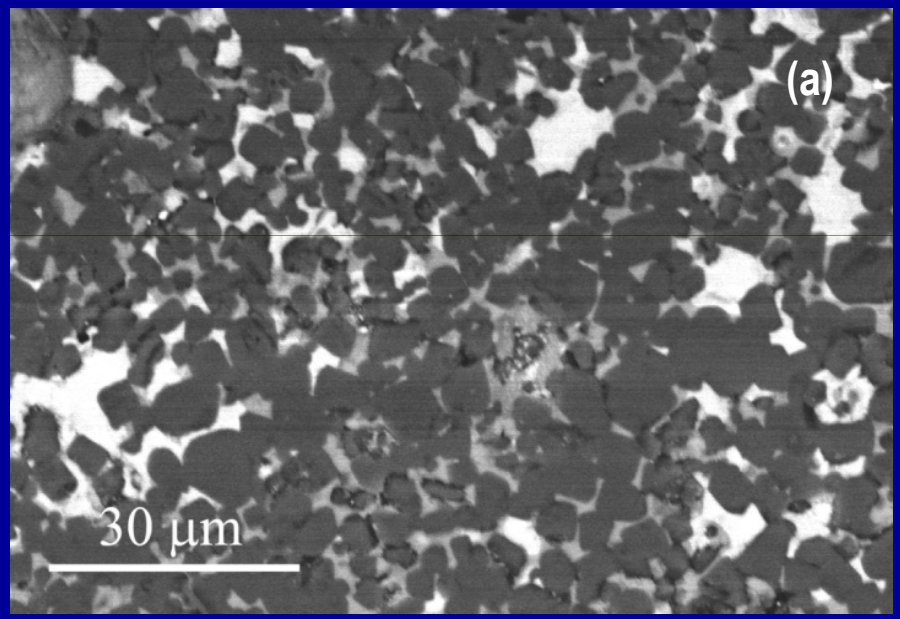
Optimized systems

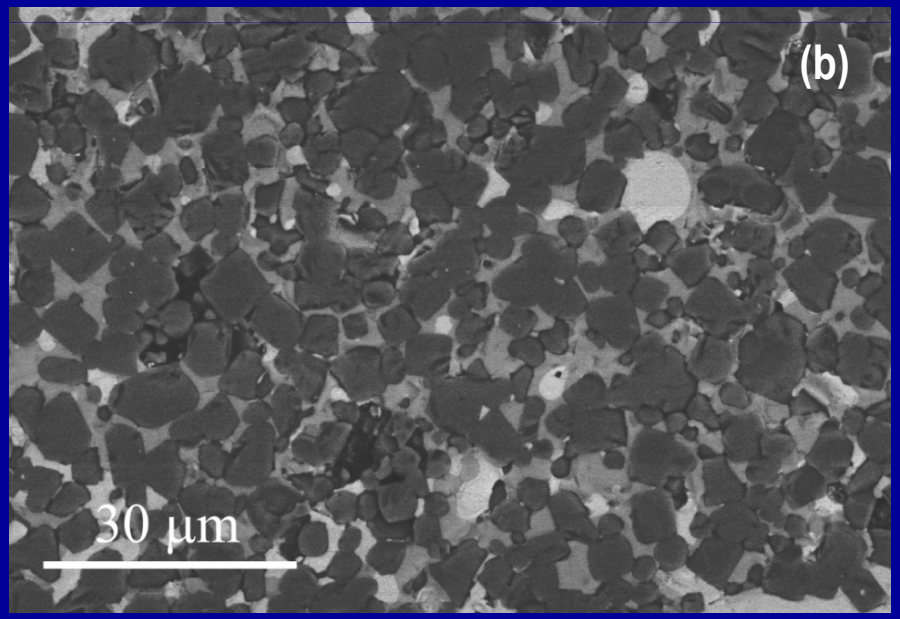
Composition of the optimal reacting mixtures as a function of the ($Al/FeTiO_3$) molar ratio used



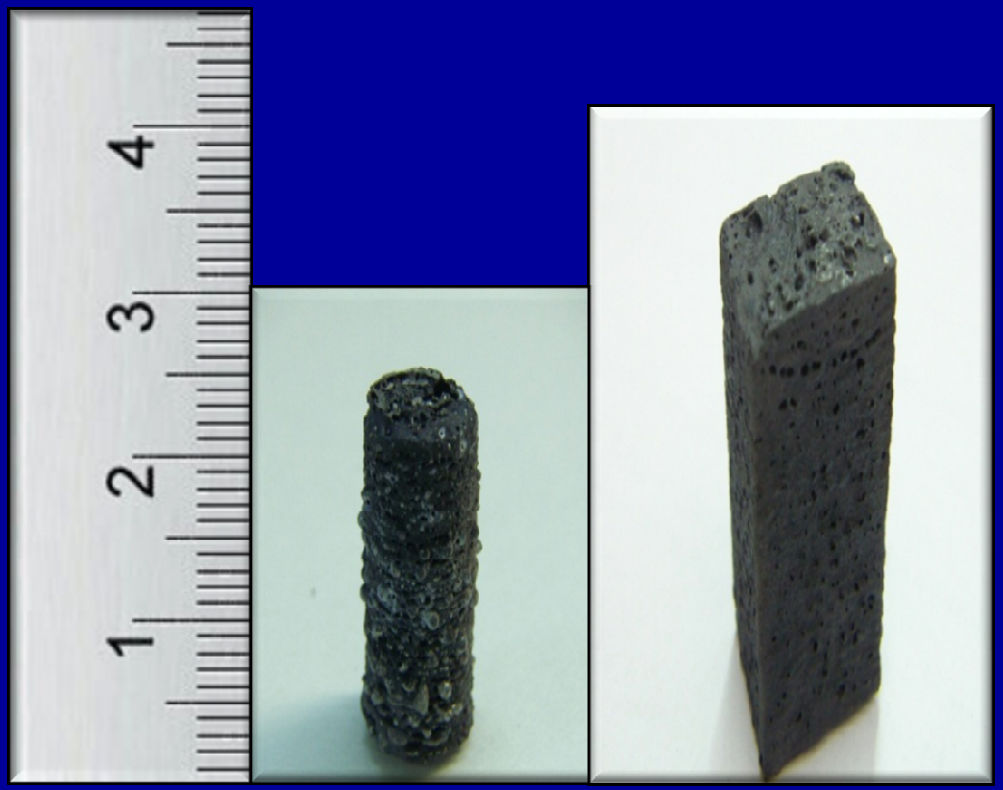
Gravity effect on microstructure

SEM microstructure of the reaction product synthesized under terrestrial (a) and low-gravity (b) conditions, respectively: S2_R_L0

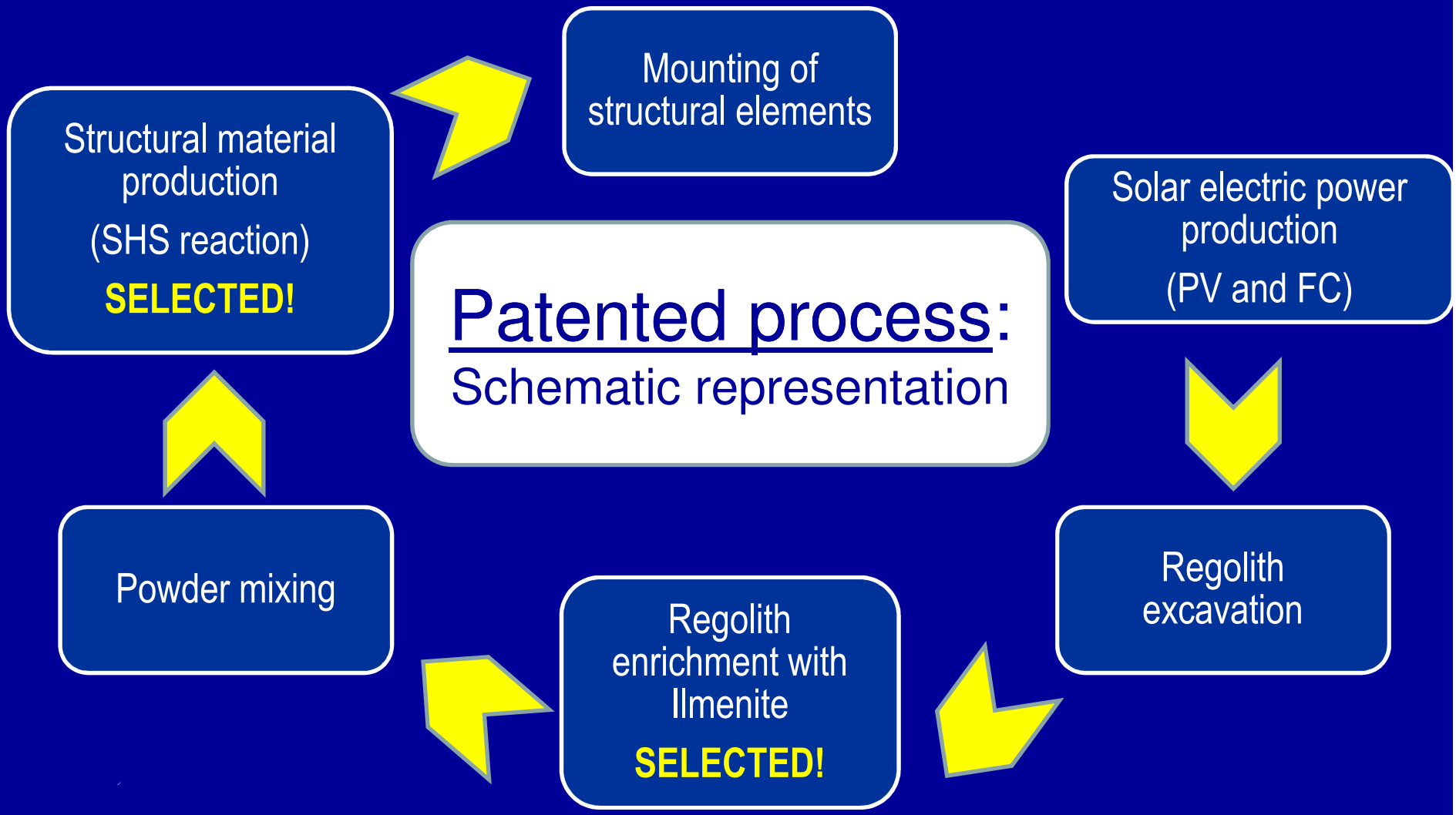




Pellet and Brick prototypes



Compressive strength measurements provided average values of 27.2 ± 3.6 and 25.8 ± 3.6 MPa, for the S2_R_L20 and S3_R_L30 systems, respectively


Mounting of structural elements
Solar electric power production (PV and FC)
Regolith excavation
Regolith enrichment with Ilmenite
SELECTED!
Powder mixing
Structural material production (SHS reaction)
SELECTED!
Patented process:
Schematic representation

What next? 10 million euros request for 3 ys since 2011

- creazione di una task force italiana per l'esplorazione robotica ed umana dello spazio

- progettazione e realizzazione di dimostratori/breadboard terrestri o per lander delle tecnologie brevettate per future missioni robotiche e umane

- sviluppo di nuove tecnologie per l'esplorazione robotica ed umana dello spazio

Is there any question?