

COMPUTATIONAL MODEL ESTIMATES OF CARDIOVASCULAR DECONDITIONING DUE TO LONG- TERM MICROGRAVITY EXPOSURE IN SPACE MISSIONS.

Dr. Antoni Perez-Poch

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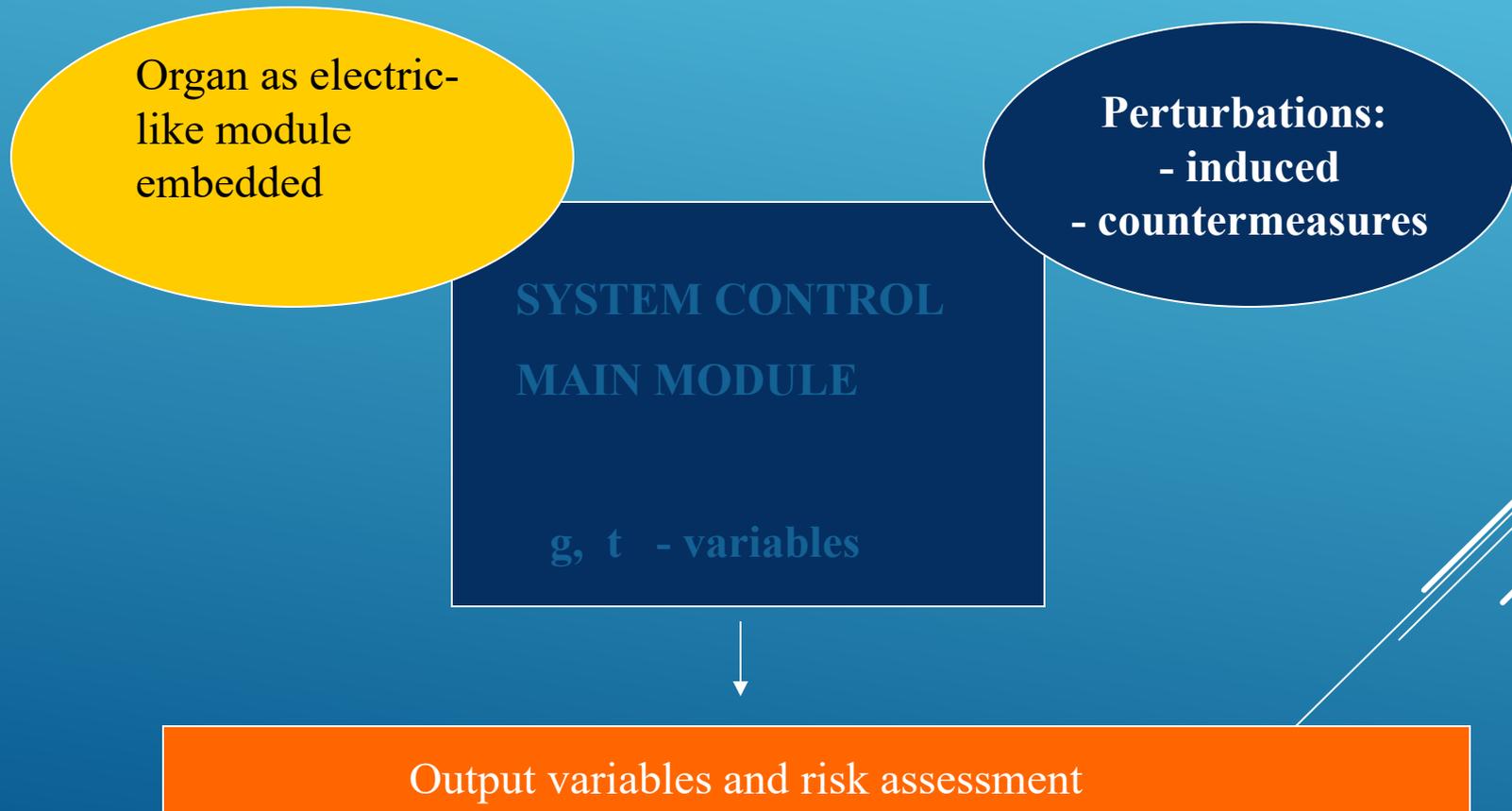
Computer Science Department

IEEC- Institut d'Estudis Espacials de Catalunya (Spain)

OBJECTIVES

- ▶ Develop a modular system to simulate human physiology at different gravities and long-term scenarios.
 - ▶ Add potential hazards & countermeasures
 - ▶ Evaluate risk probability of a major physiological malfunction
 - ▶ Study gender differences
 - ▶ Evaluate risks in Moon and Mars scenarios.
- 

NELME- NUMERICAL EVALUATION OF LONG-TERM EFFECTS



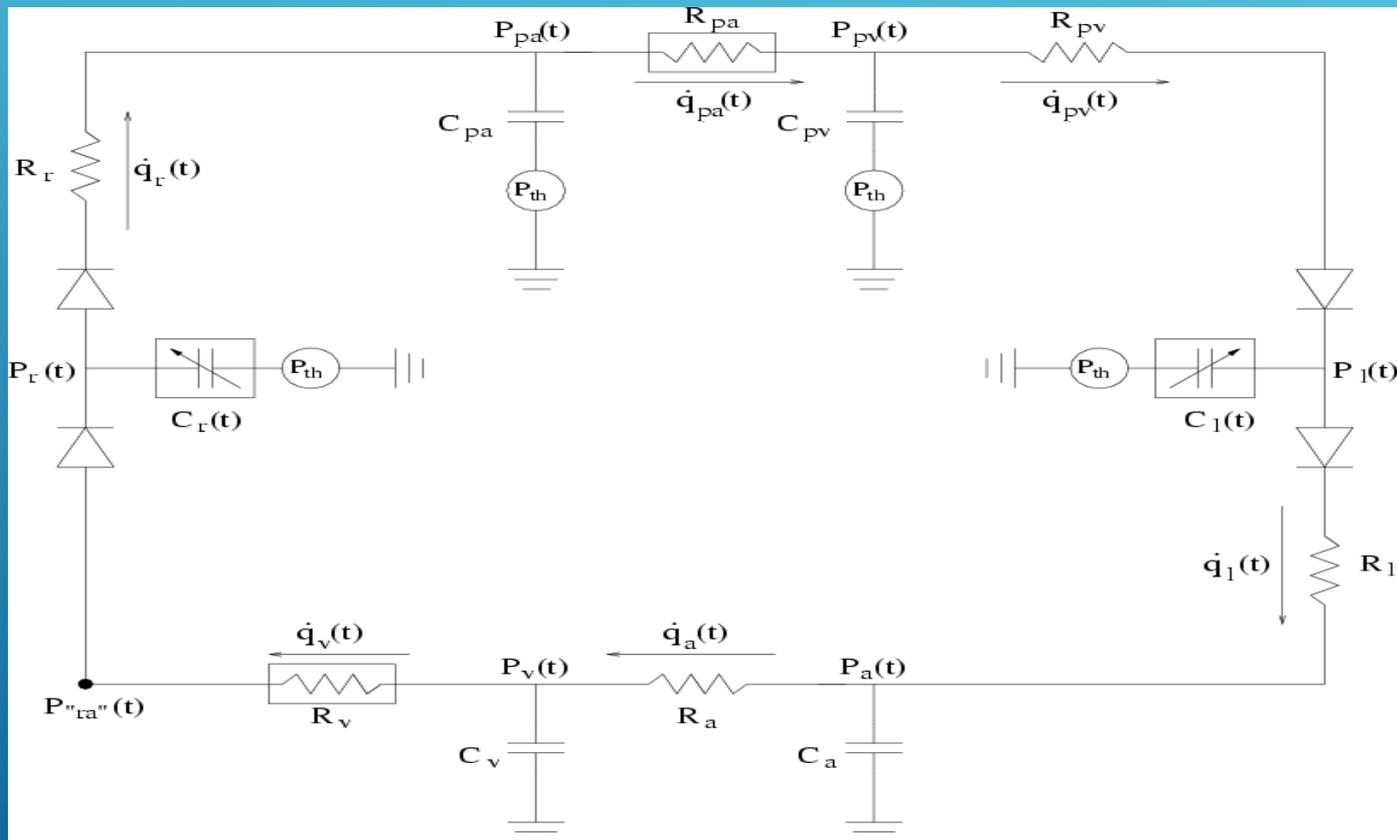
DEVELOPMENT

- Based on models for Orthostatic intolerance

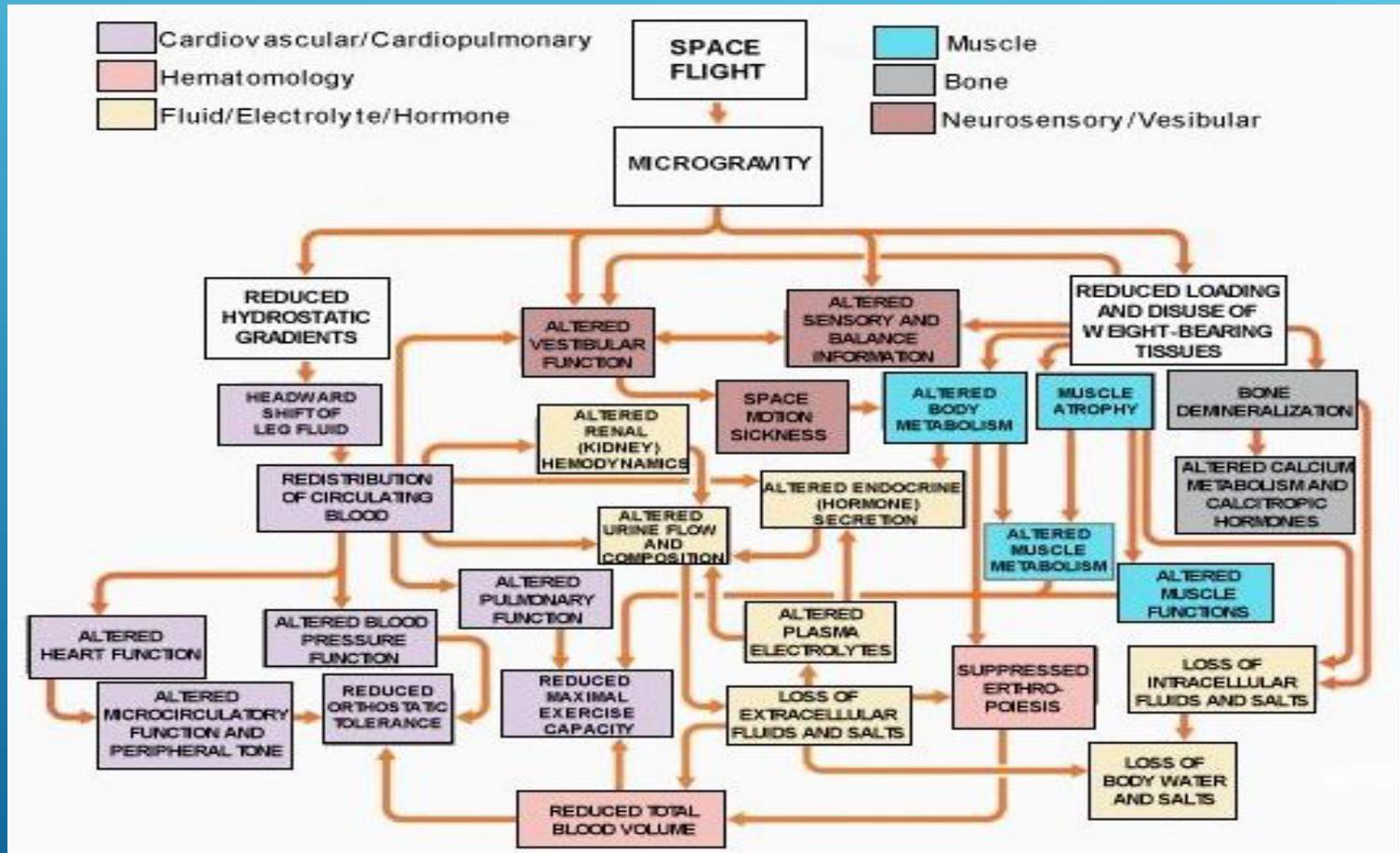


- 12 first-order diff.equations 4th ord Runge-Kutta
Electrical-like model
- Include models which reproduce influence of shift volume to organ performance.

electrical-like model



INTEGRATING PHYSIOLOGY

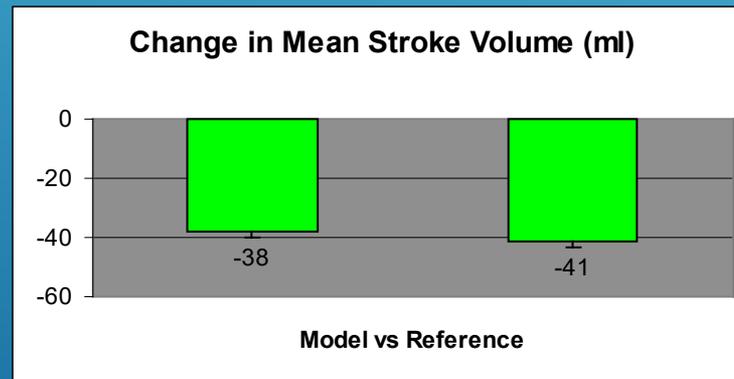
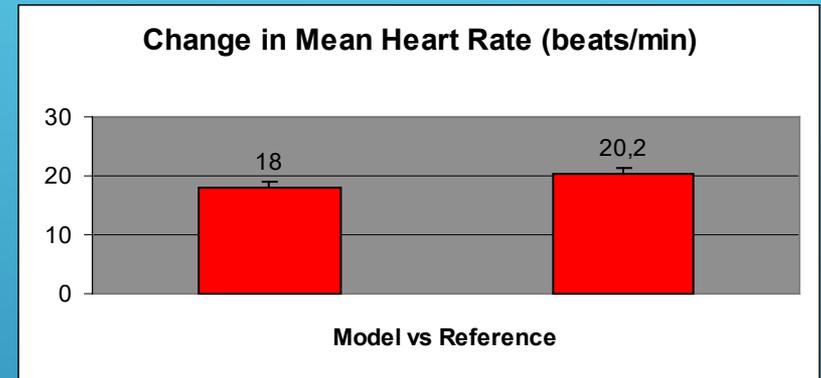
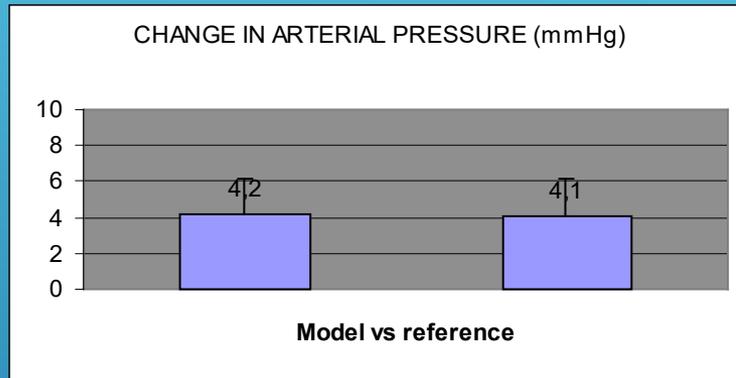


Whole-body algorithm SLS-1

PREVIOUS WORK

- ▶ VALIDATION :Assess accuracy of model at zero-g --- compared to published data.
- ▶ Orthostatic intolerance assessment compared to experimental data
- ▶ Diaz-Artiles A., Heldt T., Young L.R., “Computational model of cardiovascular response to centrifugation and lower-body cycling exercise”. J. Appl. Physiol. (2019).

INITIAL WORK: VALIDATION RESULTS

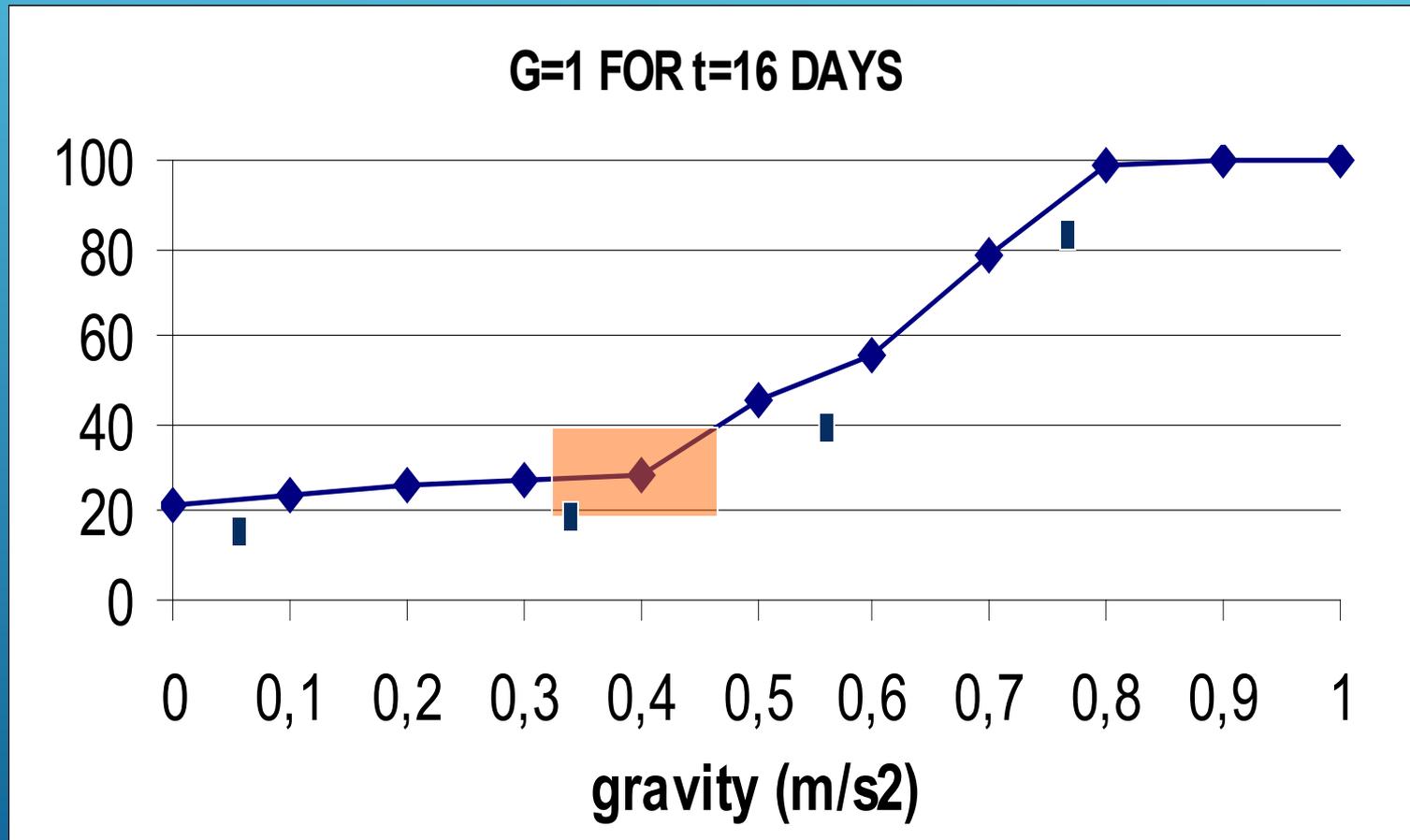


Reference: Heldt T. et al, J. Appl Physiol 92; 1239-1254, 2002.
Computational modeling of cardiovascular response to orthostatic stress.

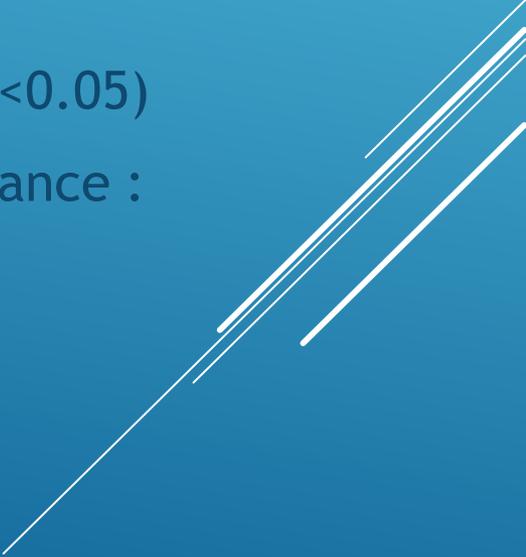
PULMONAR MODULE TEST

- ▶ C-R model with nearly no L component
- ▶ G: 0-1 g steps 0.01
- ▶ $G < 0.43$; $t > 16$ days
 - ▶ 30% vascular resistance ($p < 0.05$ over $g=1$)
- ▶ Risk assessment 1%
 - ▶ Above 69 days , $g < 0.01$
- ▶ Raises up to 1.3% when extending t up to 2 years

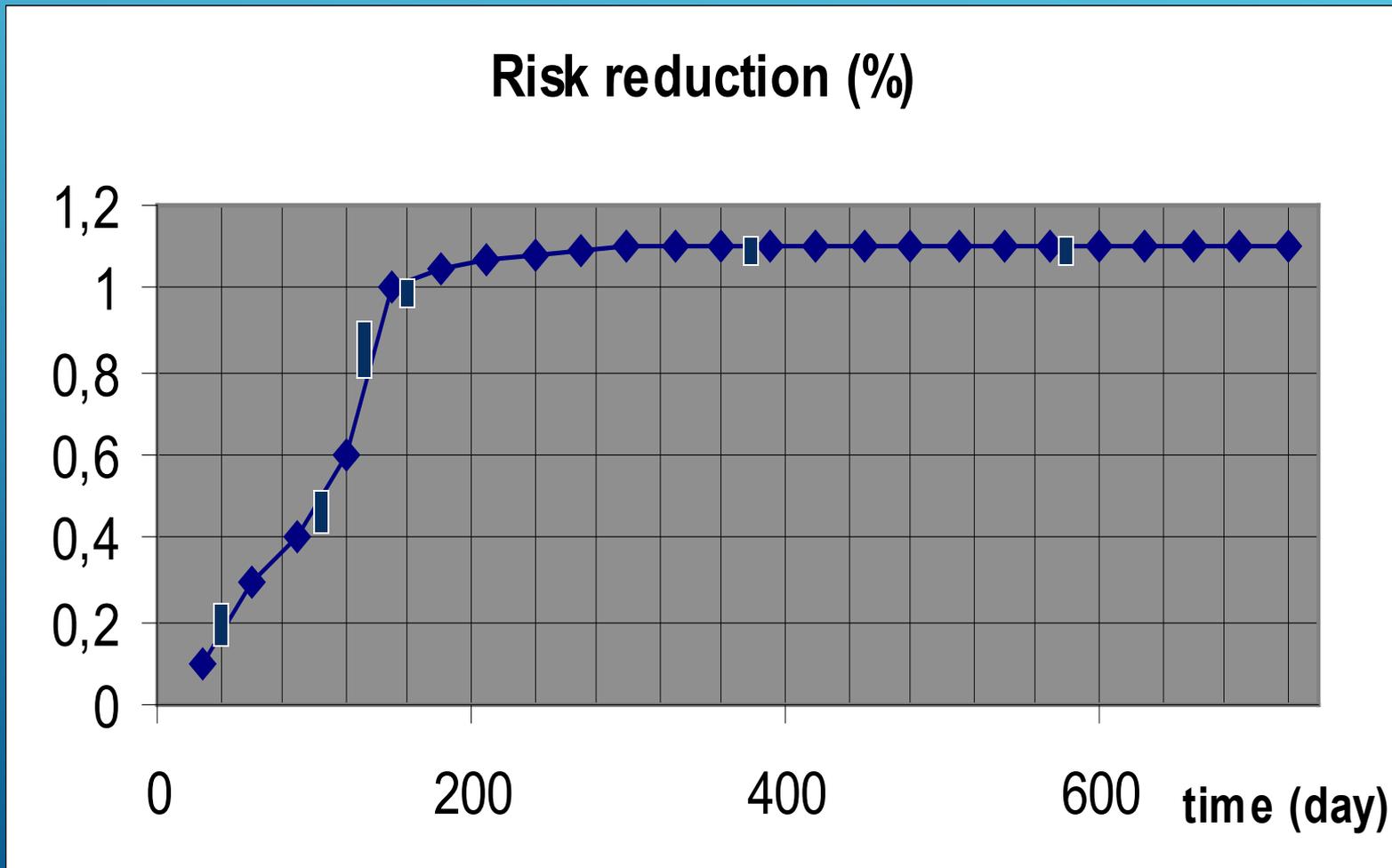
Vascular Resistance (% at g=1)



EXERCISE AS COUNTERMEASURE

- ▶ Pattern of aerobic exercise applied 30 minutes/day - 60 minutes - 90 minutes
 - ▶ Overall risk 1% reduced to 134+/- 12 days ($p < 0.05$)
 - ▶ Final step to 1-g assessing orthostatic intolerance :
 - ▶ Hypovolemia decreased 19 +/- 4%
- 

EXERCISE AS A COUNTERMEASURE



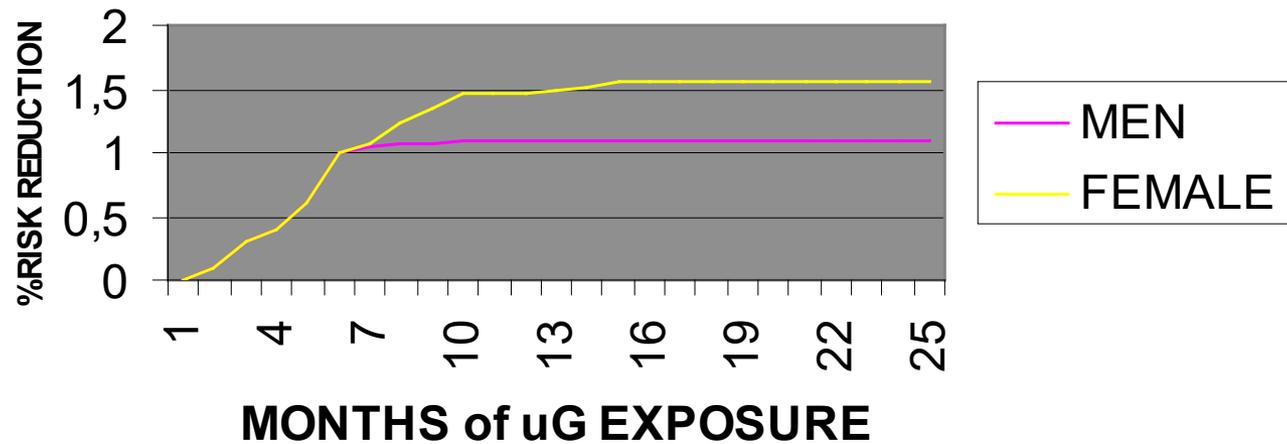
THERMAL DISTRESS

- ▶ Based on R-T(°C) dependence on model
- ▶ Thermal applied t= 2-8 hours 3 times/1 week
- ▶ Initial values add 1.5 % risk , linear

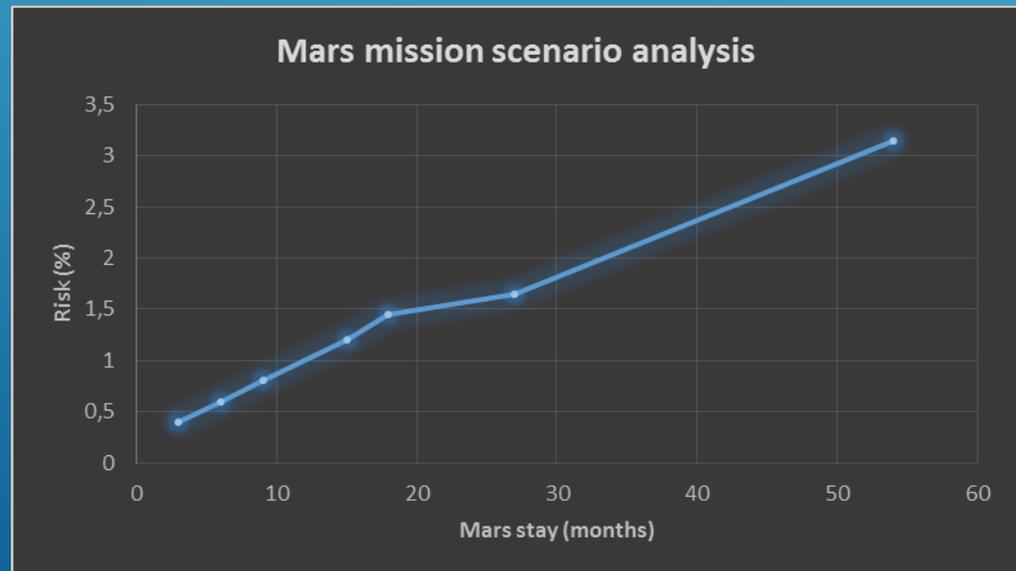
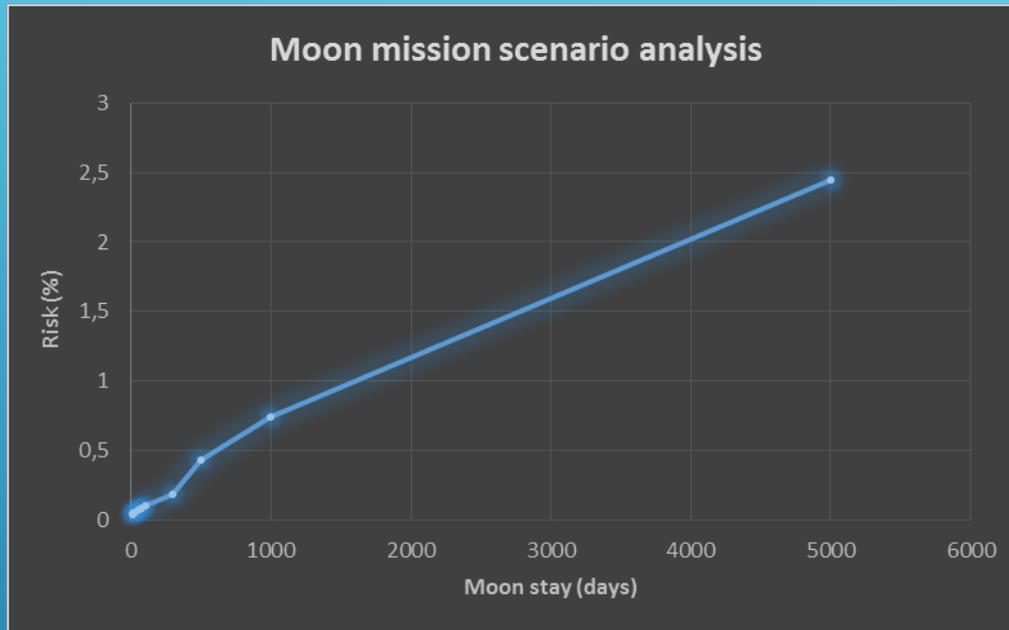
Longer missions : tests show no dependance on elapsed time

GENDER DIFFERENCES

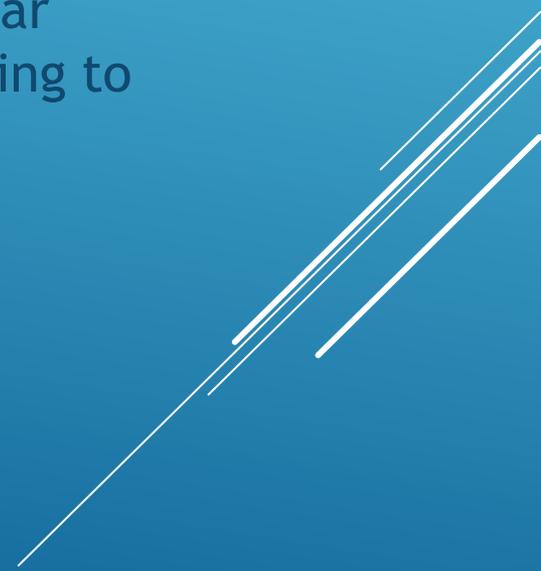
RISK REDUCTION - AEROBIC EXERCISE



MOON AND MARS SCENARIOS - RISK ANALYSIS



CONCLUSIONS 1/2

- ▶ Numerical modeling is a valuable tool to predict possible risks of developing hazards in long-term mission scenarios.
 - ▶ Electrical-like Model reproduces cardiovascular changes from previous modelling when returning to Earth.
- 

CONCLUSIONS 2/2

- ▶ Significant differences in heart rate output, mean arterial pressure and mean stroke volume appear in short-term scenarios.
 - ▶ Significant differences ($p < 0.05$) appear in long-term exposure risk reduction, after aerobic exercise pattern applied, women's higher than men's.
 - ▶ Exposure risks can be estimated for manned Moon and Mars scenarios, within safety limits.
- 

COMPUTATIONAL MODEL ESTIMATES OF CARDIOVASCULAR DECONDITIONING DUE TO LONG- TERM MICROGRAVITY EXPOSURE IN SPACE MISSIONS.

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THANK YOU FOR YOUR ATTENTION !



IEEC^R

Institut d'Estudis
Espacials de Catalunya



Research in microgravity

Human reproduction, immunology and
human physiology

+ The Barcelona ZeroG Challenge

Dr. Antoni Perez-Poch

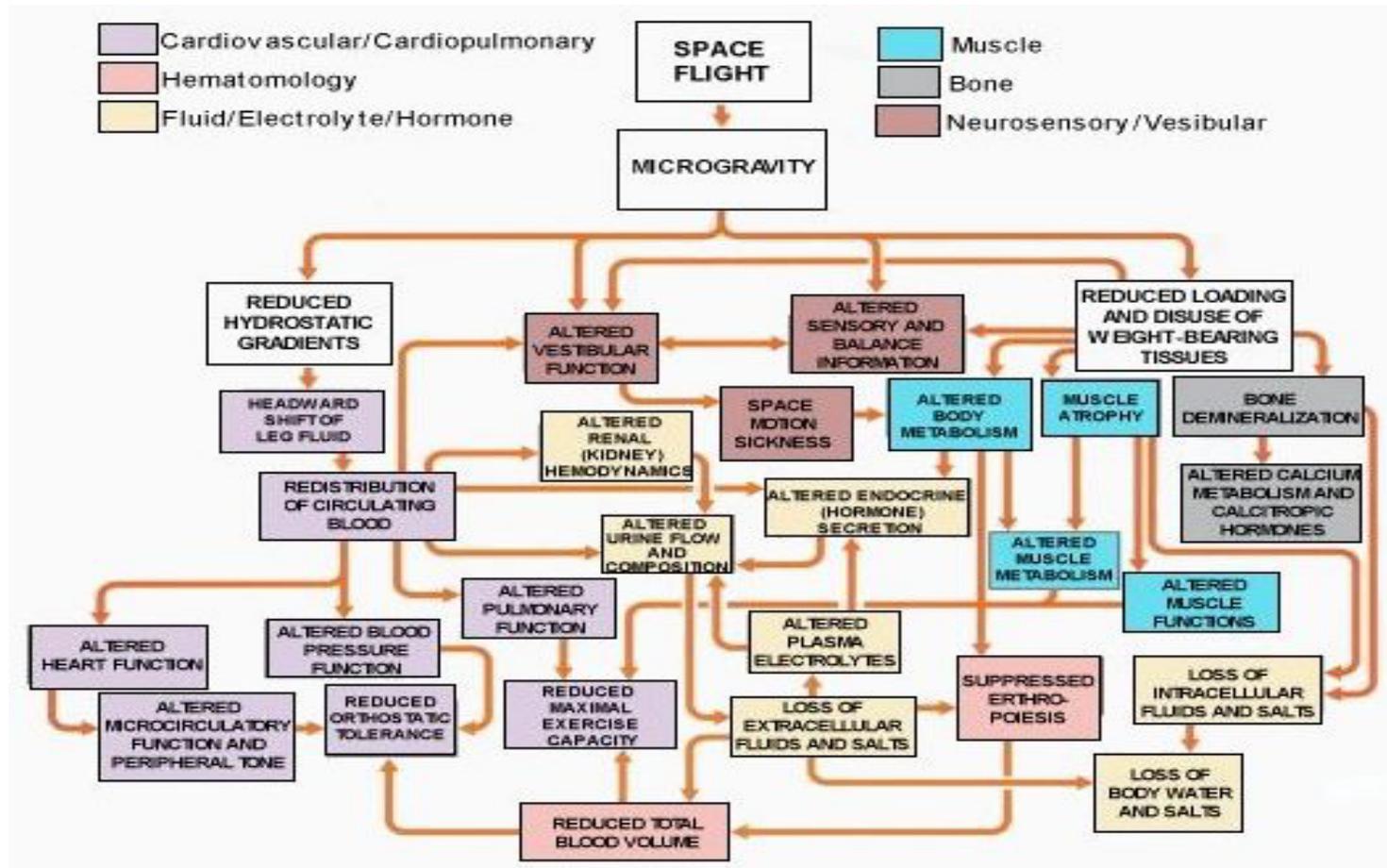
Universitat Politècnica de Catalunya- BarcelonaTECH (Spain)

Computer Science Department

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Centres de Recerca
de Catalunya



Whole-body algorithm SLS-1

Cardiovascular
system

Osteoporosis

Space Radiation

Muscular distress

Psychology

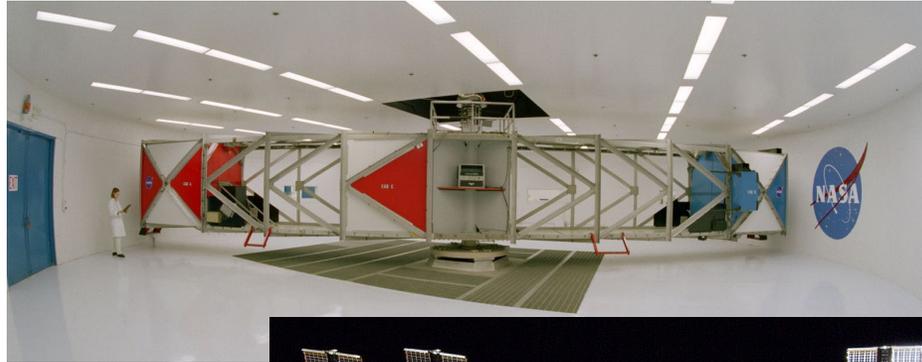
Immuno system



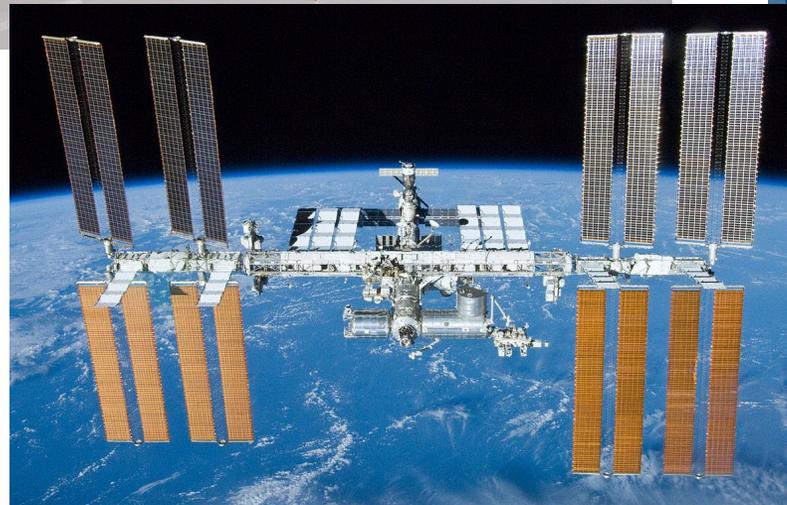
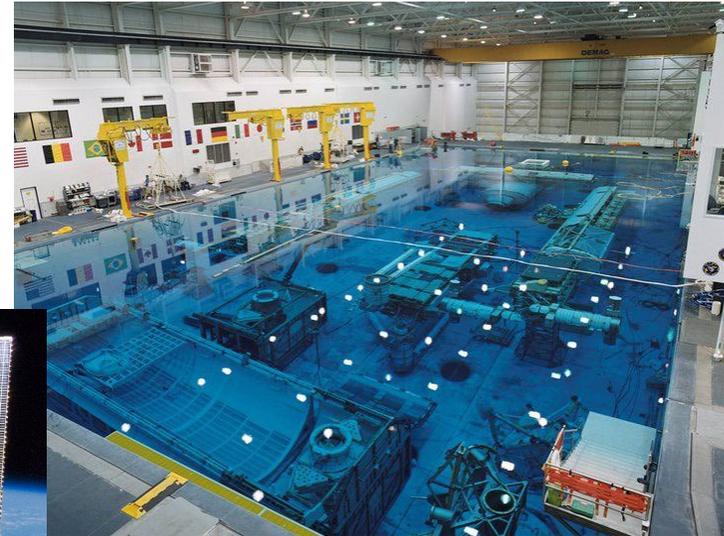
Spaceflight effects on human body– Beau and Alan Daniels

Space Exploration: gravity loads

Hypergravity

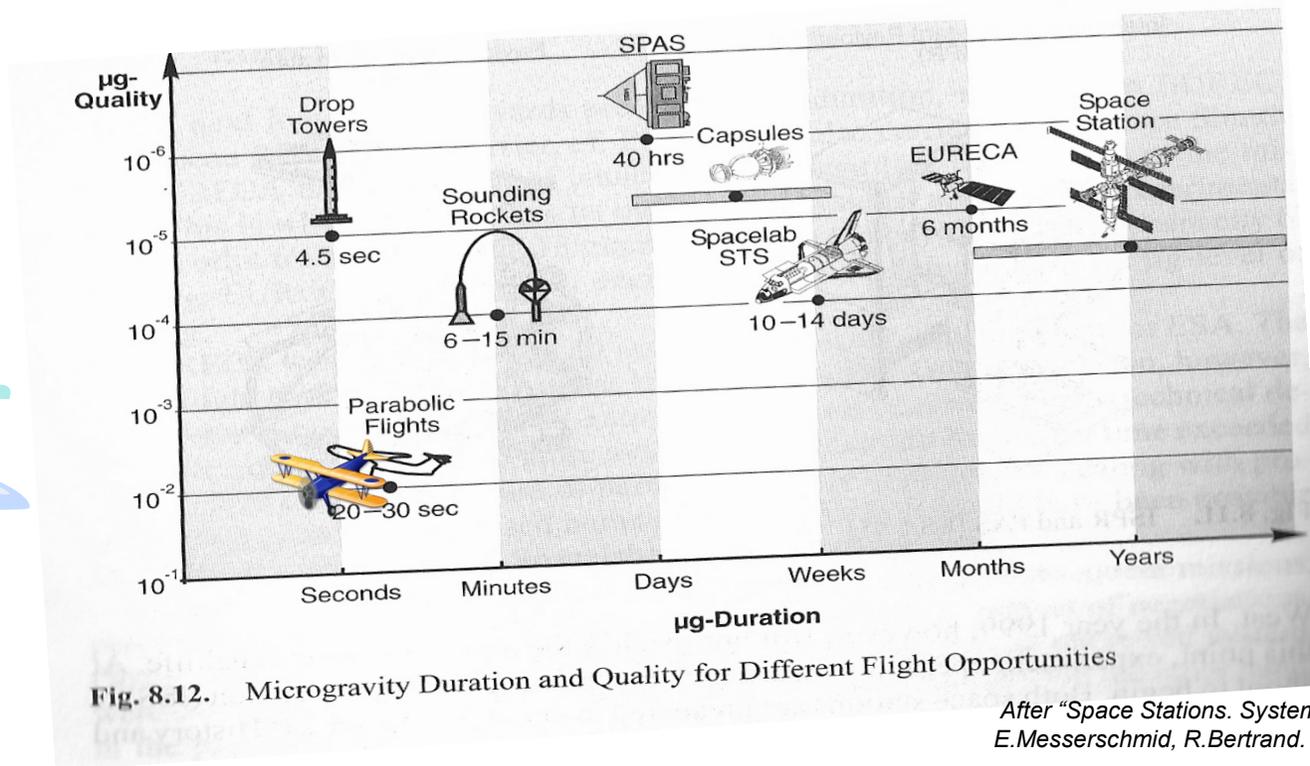


Hypogravity, reduced gravity



Microgravity

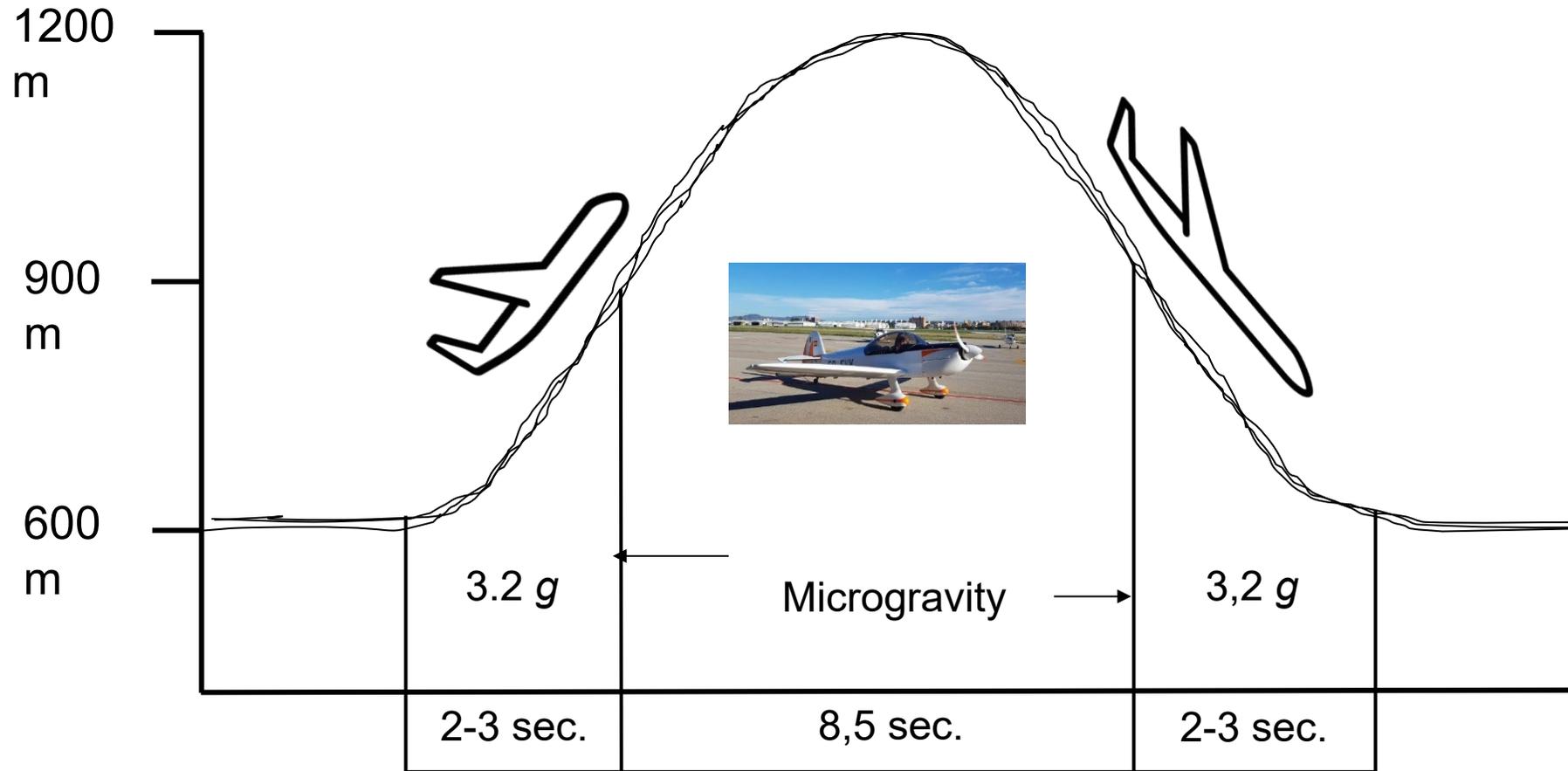
Microgravity platforms



Clinostat // RPM:
Random Position Machine
(simulated microgravity)

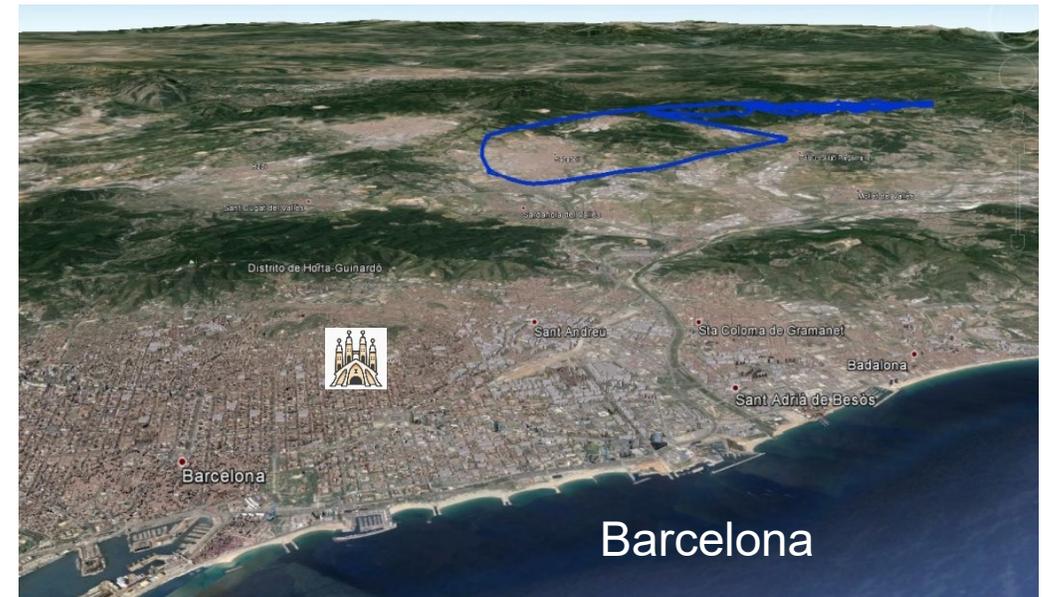
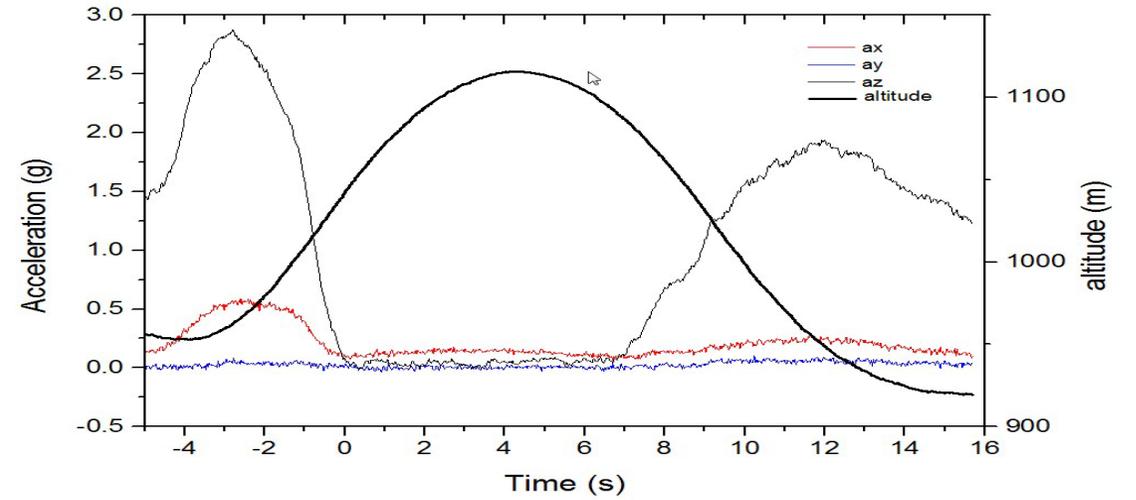
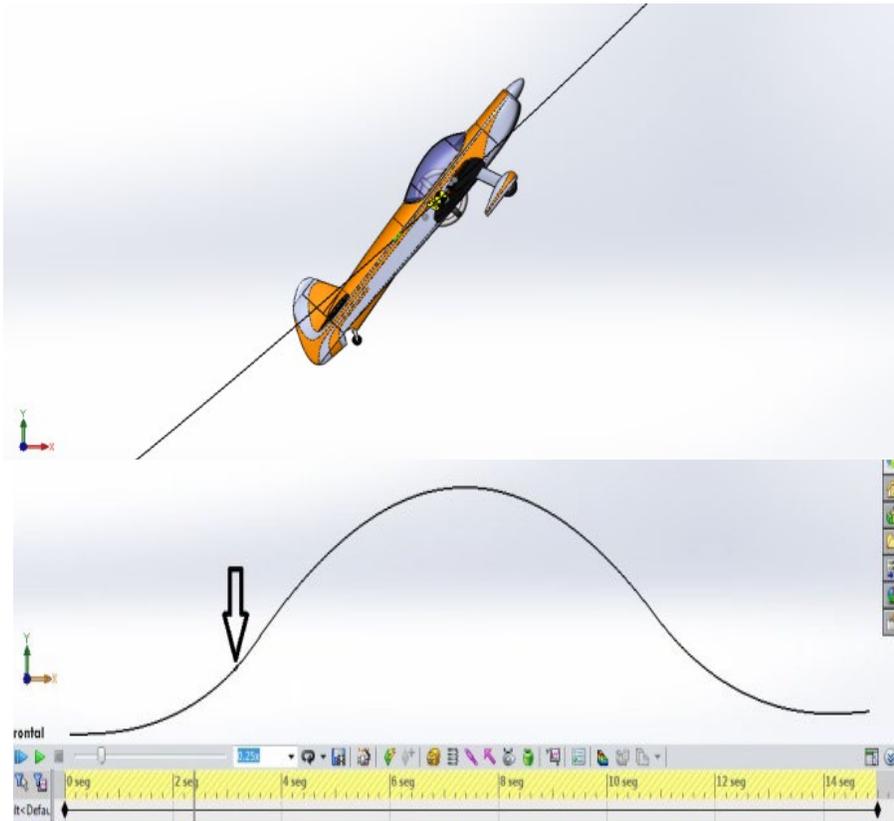
Torner J.; Brigos, M.; Perez-Poch, A.; Alpiste, F. **Dispositive for achieving absence of gravity in a light aircraft..**
Registration number: **P201431164. Invention patent.** Date of registration: 31/07/2014, Spain. Property-holding institution: Universitat Politècnica de Catalunya. Company: Aeroclub Barcelona-Sabadell.

Parabolic flights: light aerobatic aircraft



Perez-Poch A., González D.V., López D., "Hypogravity research and educational activities in Barcelona: a new hub of innovation in Europe", *Microgravity Science and Technology* (2016). doi:10.1007/s12217-016-9516-7

Flight operations

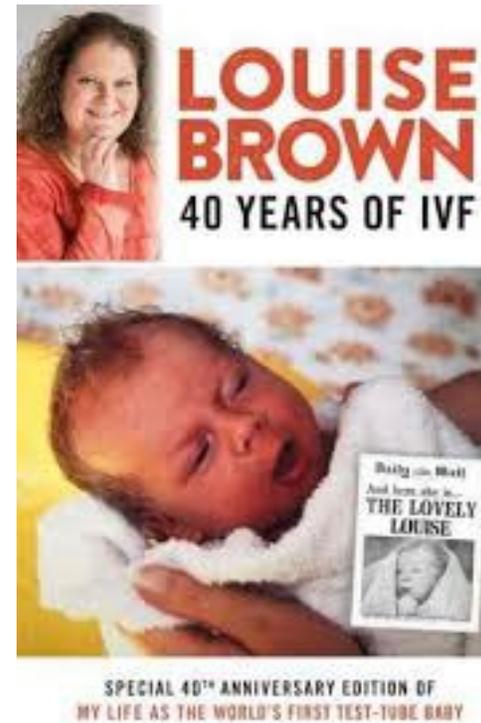


Brigos M., Perez-Poch A. et al. "Parabolic flights with single-engine aerobatic aircraft: flight profile and a computer simulation for its optimization." *Microgravity Science and Technology*. 4, 26, 229-239 (2014).

Human Reproduction: role of microgravity & ART



IVF on Earth...



Men's fertility

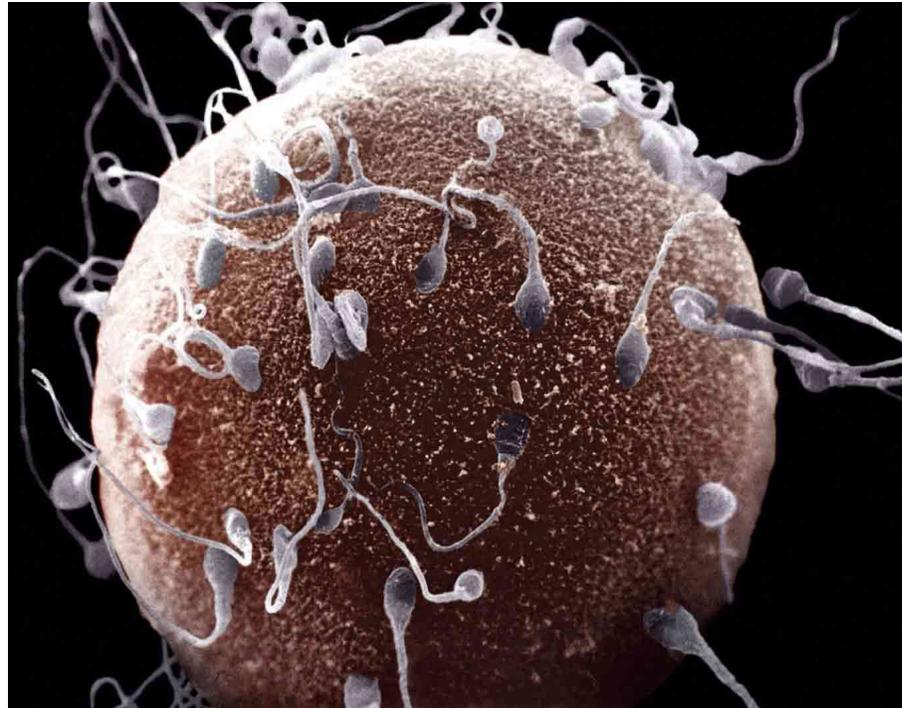
Fertility in men is defined by the quality of its sperm.

Seminogram

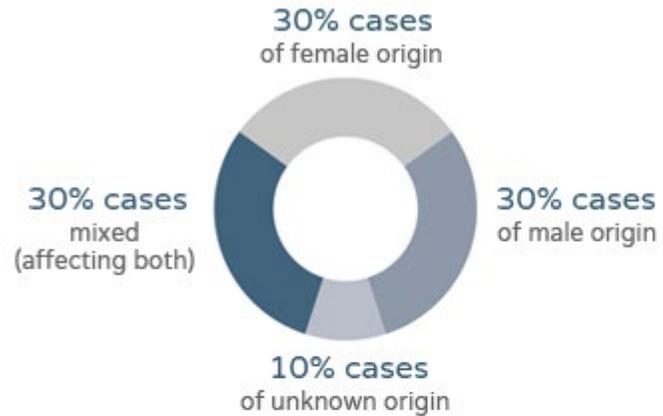
Volume
Seminal PH
Viscosity
Presence of other cells
DNA analysis

Spermatozoa Concentration
Spermatozoa Motility
Spermatozoa Morphology

250 million sp. typically
525 billion sp. in a lifetime !



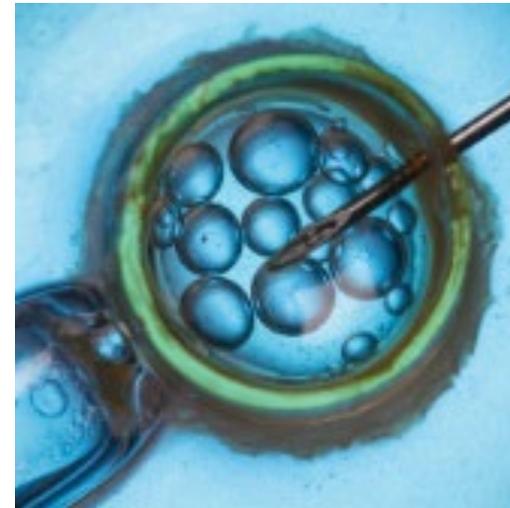
Assisted Reproductive Techniques (ART)



- [In Vitro Fertilization \(IVF\)](#): Most common ART
 - Complication: multiple pregnancy
- [Criopreservation](#) of gametes or embryos

More common than you think

Fertility disorders affect **15%** of couples wanting to have children.



...and in Space? ... the role of microgravity?

Journal of Andrology, Vol. 24, No. 6, November/December 2003
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Effect of Simulated Microgravity on Testosterone and Sperm Motility in Mice

HIROYUKI KAMIYA,* SHOICHI SASAKI,* TAKAHITO IKEUCHI,* YUKIHIRO UMEMOTO,*
HIROYUKI TATSURA,* YUTARO HAYASHI,* SHIGEO KANEKO,† AND KENJIRO KOHRI*

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Detrimental Effects of Microgravity on Mouse Preimplantation Development In Vitro

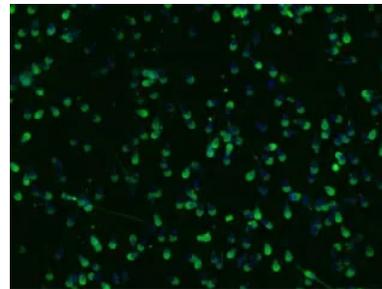
Sayaka Wakayama¹, Yumi Kawahara², Chong Li^{1,3}, Kazuo Yamagata¹, Louis Yuge², Teruhiko Wakayama^{1,3*}

¹Laboratory for Genomic Reprogramming, RIKEN, Center for Developmental Biology, Kobe, Japan, ²Division of Bio-Environment Adaptation Sciences, Graduate School of Health Sciences, and Space Bio-Laboratories, Hiroshima University, Hiroshima, Japan, ³Department of Bioscience, Graduate School of Science and Technology, Kwansei Gakuin University, Sanda, Japan

In humans:

- Preliminary results had been published by Ikeuchi T et al. (*Reprod Med and Biol*, 2005) with a decrease in sperm linear motility from a jet parabolic flight, but no differences were found when compared to 2G exposure or within a Clinostat.

Micro-11 Experiment (NASA, 2018)



Zero-g aerobatic flight: Mudry CAP10B (2020)



Future IVF in Space... ?



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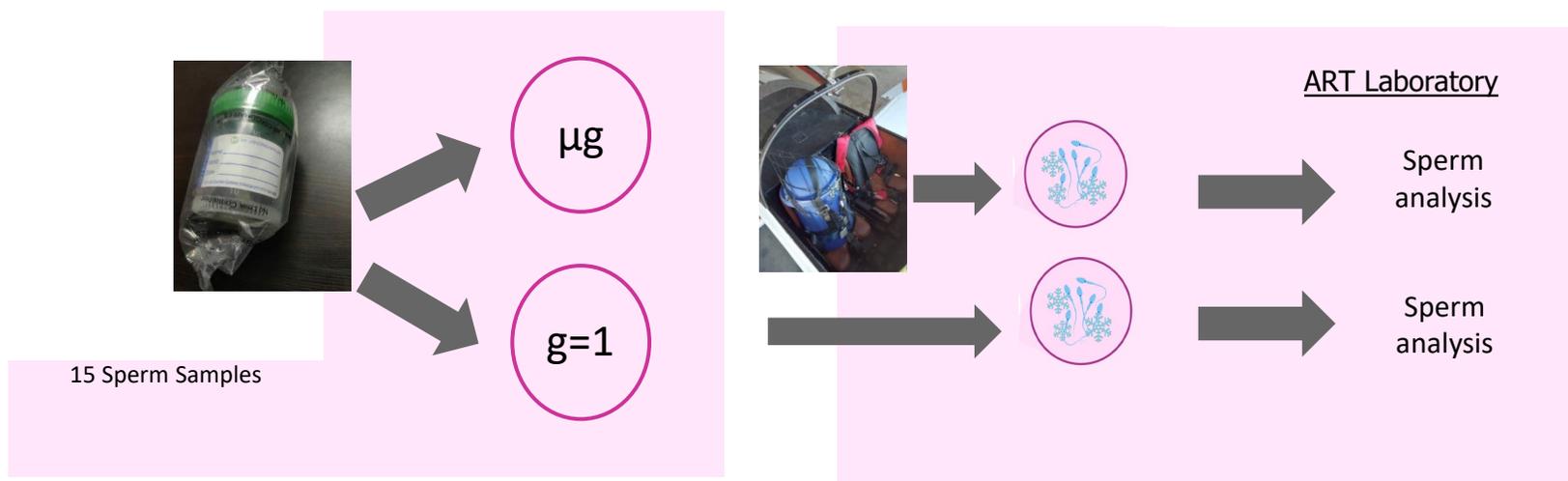


CSmicro ^g lab
Computer Science & Microgravity LAB



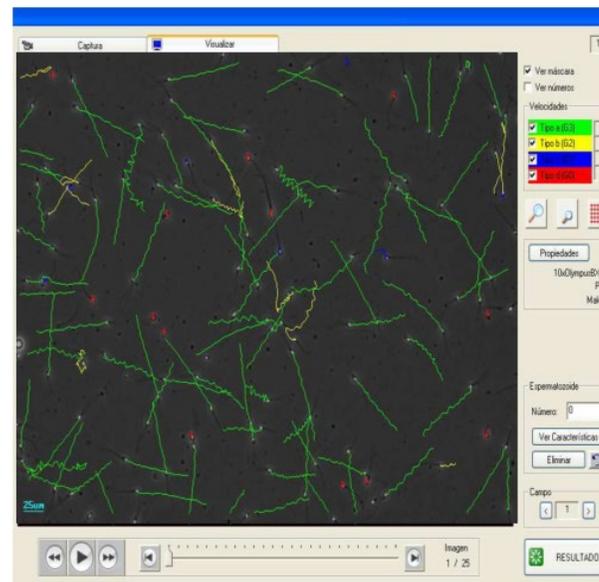
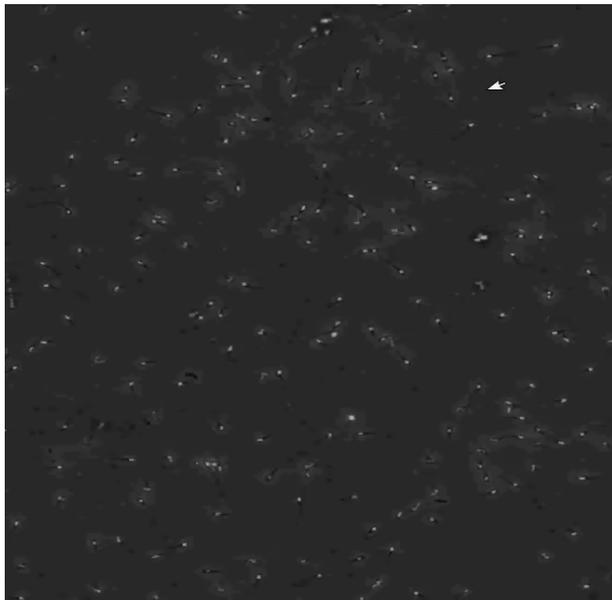
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Material and Methods



Sperm Analysis

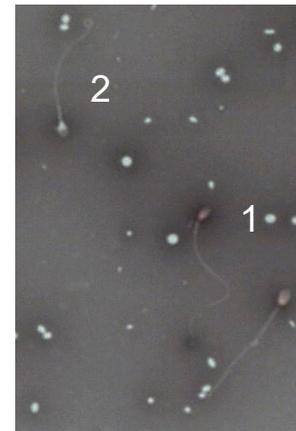
Dexeus
mujer



SCA® CASA System
(Microptic)

- green (progressive) $>25 \mu\text{m/s}$
- yellow (progressive $>5 \mu\text{m/s}$)
- blue (in situ)
- red (immotile)

TESTING:
- CONCENTRATION
- MOTILITY
- VITALITY

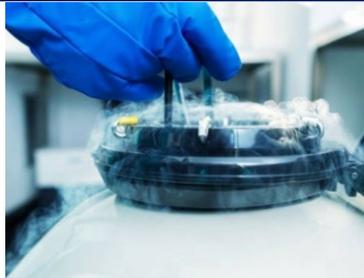


eosin-nigrosin staining
(VitalScreen-FertiPro)

1. Dead Spermatozoa - pink head
2. Intact Spermatozoa - white head

Considering the creation of a Sperm Bank outside Earth

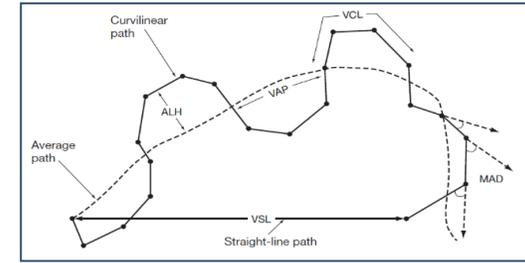
The lack of differences previously observed in the sperm characteristics between **frozen samples** exposed to microgravity and those maintained in ground conditions **opened** the possibility of considering safely transporting male gametes to space and **the possibility of creating a Human Sperm Bank outside Earth.**



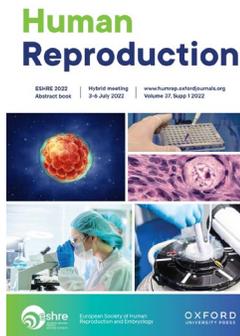
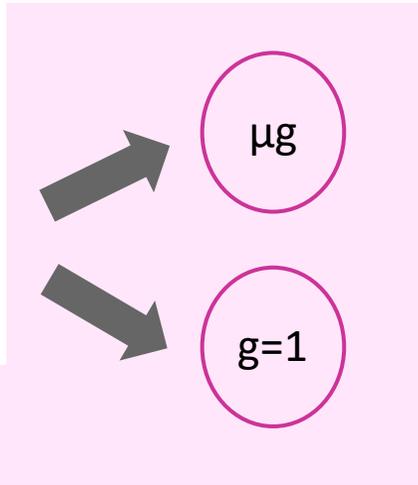
Boada, M.; Perez-Poch, A.; Balester M.; García-Monclús S., González D.V.; García S.; Barri P.N.; Veiga A. (2020) "Microgravity effects on frozen human sperm samples." *Journal of Assisted Reproduction and Genetics*, 37,6, 2249-2257



Effects of microgravity on human sperm samples (2022)



15 Sperm Samples



Significant alterations in **Sperm Movility, Motility and Vitality** ($p < 0.05$):

- **Sperm Curvilinear Velocity** ($\mu\text{m/s}$) **VCL**
 45.7 ± 12.8 vs 47.7 ± 13.3
- **Progressive a+b Sperm Motility** (%)
 30.0 ± 12.9 vs 47.7 ± 13.3
- **Sperm Vitality** (%)
 44.62 ± 9.34 vs 46.42 ± 10.81

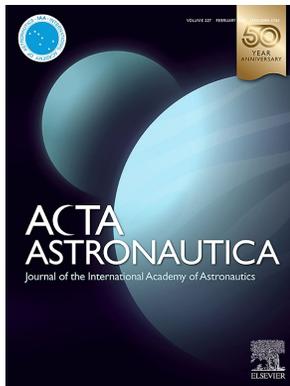
No significant differences in **overall Sperm Concentration** were found:

$81.7 \pm 112,1$ vs $79,7 \pm 89,8$ M/ml

Boada, M., Perez-Poch et. al. Microgravity exposure significantly decreases sperm motility and vitality. Can we consider human reproduction outside the Earth? *Human Reproduction* (2022), 37, Supplement_1, p. 1-2.

Sperm Motility and Vitality are significantly reduced after parabolic flight

- Natural samples: **Sperm Motility and Vitality are decreased** in microgravity conditions only after a brief exposure to parabolic flight (just 160 seconds !!!) .
- More studies are needed to assess whether human reproduction space in space may be impeded by this decrease in motility.
- Other major factors such as Radiation and Psychological issues have not been studied yet.
- A full understanding of the likelihood of **Human Reproduction in Space** will require more research in the upcoming years.

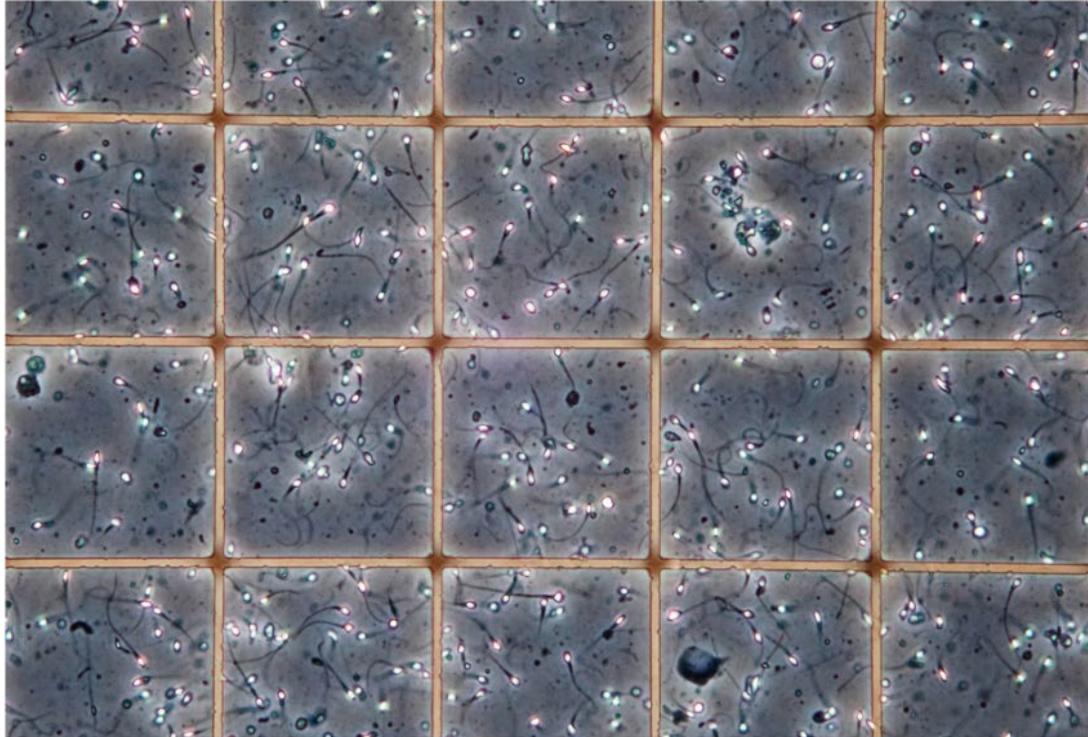


Decreased human sperm motility and vitality after fast gravity load changes in a parabolic flight

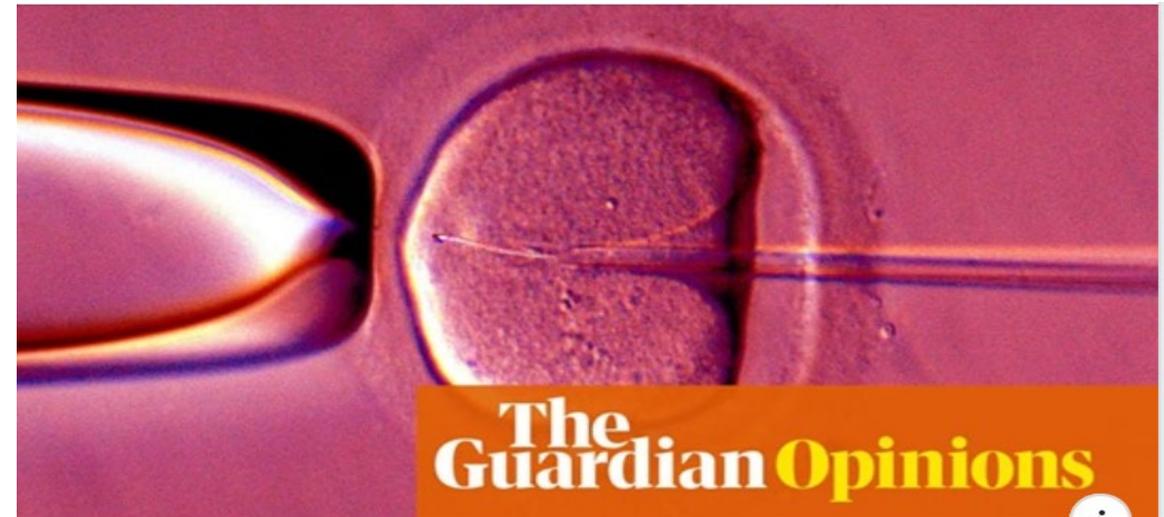
Antoni Perez-Poch ^{a,f,*}, Marta Ballester ^b, Marta Tresanchez ^b, Jordi Torner ^a, Daniel V. González ^c, Francesc Alpiste ^a, Miguel Brigos ^a, Eduard Sánchez ^d, Gloria Martínez ^d, Sandra García ^e, Nikolaos P. Polyzos ^b, Montserrat Boada ^b

Scientists Take Baby Steps Toward Extraterrestrial Babies

Can sperm survive microgravity? Do eggs hold up to radiation? The new science of off-planet procreation is now getting underway.

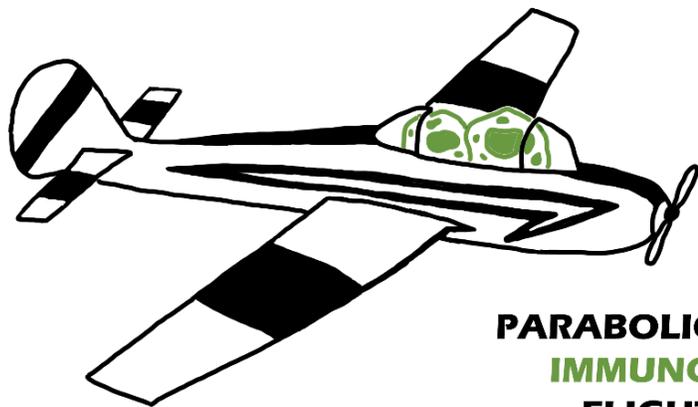


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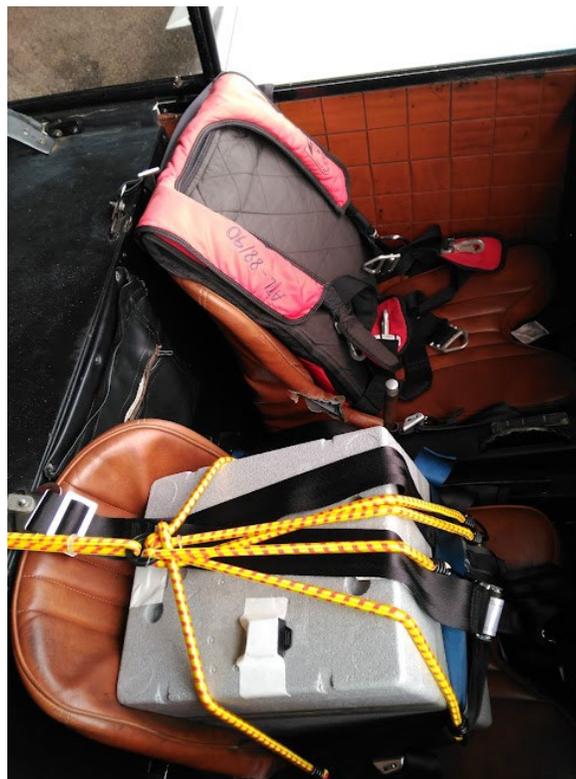
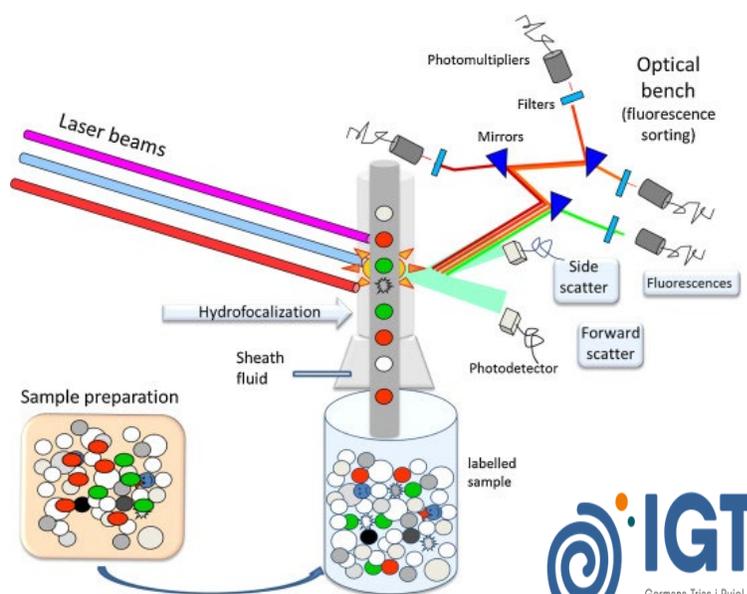


THEGUARDIAN.COM

Have sperm will travel. But what would an all-female planet look like? | Stephanie Merritt



**PARABOLIC
IMMUNO
FLIGHT**



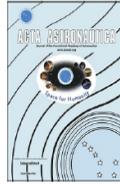


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Acta Astronautica

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Effects of rapid gravity load changes on immunophenotyping and leukocyte function of human peripheral blood after parabolic flight

Abril Gorgori-González^{a,*}, Antoni Perez-Poch^b, Daniel V. González^c, Roser Salvia^d, Laura G. Rico^d, Michael D. Ward^e, Jolene A. Bradford^e, Jordi Petriz^d, Ginés Viscor^a

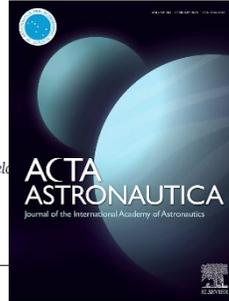
^a Department of Cell Biology, Physiology and Immunology, Universitat de Barcelona, Av. Diagonal, 643, Barcelona, Spain

^b Universitat Politècnica de Catalunya, Institut d'Estudis Espacials de Catalunya (IEEC). EEBE Campus Diagonal-Besòs, c. E. Maristany 16, ES08019, Barcelona, Spain

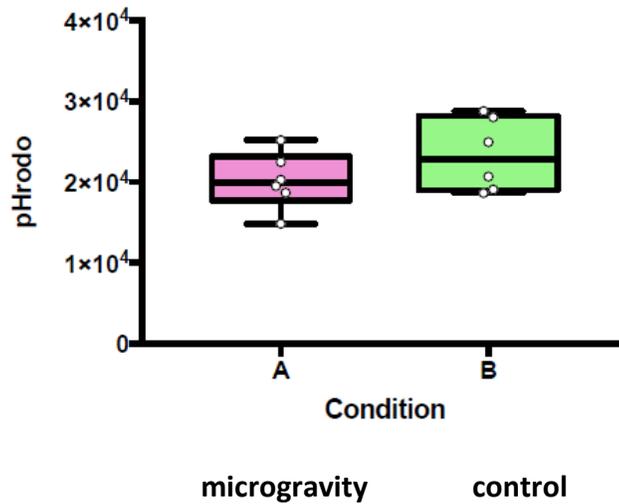
^c Barcelona-Sabadell Aviation Club, Sabadell Airport, ctra. Bellaterra s/n, ES08205, Sabadell, Barcelona, Spain

^d Germans Trias i Pujol Research Institute (IGTP), Ctra de Can Ruti, Camí de les Escoles s/n, 08916, Badalona, Barcelona, Spain

^e ThermoFisher Scientific, Eugene, OR, USA



Single cells (Phagocytes)



+ The Barcelona ZeroG Challenge



BARCELONA ZEROG CHALLENGE

Win an Aerobatic Zero-G Flight for your experiment along with → 500 euro-grant for your microgravity research team

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 **SPACE GENERATION ADVISORY COUNCIL**

 **L'AEROCUB BARCELONA SABADELL**

BUILD YOUR TEAM:

2-4 university students
(undergrad, MSc, PhDs)
+ endorsing Mentor

Interdisciplinary
International
Diverse

Meet the requirements of
the zeroG platform !!!

Think Safety +
Outreach plan

Twitter: @BarcelonaZeroG

Information & Submission: <http://window2theuniverse.org>
OPEN FOR SUBMISSIONS



Al infinito y más allá

Vera Gravitas está conformado por cuatro ingenieras aeroespaciales y mecánicas, cuyo objetivo es visibilizar a la mujer como parte de varios proyectos de investigación científica. Recientemente ganaron el Barcelona ZeroG Challenge, un concurso que reta a los estudiantes de todo el mundo a diseñar un experimento para volarlo en gravedad cero. / Tema del día p. 2



SEDS/H

CONGRATULATIONS!

Juan Migelle Ferido Danielle Sumanoy Baldono Michelle Dote Leonardo Florenz Eugenio

for winning the
BARCELONA ZERO-G CHALLENGE 2024!

@seds_ph @seds_ph @SEDSPH



Thank you for your attention!



CSmicro ^g lab
Computer Science & Microgravity LAB



<http://CSmicrogLab.upc.edu>
Contact: Prof. antoni.perez-poch@upc.edu
<https://www.linkedin.com/in/antoniperezpoch/>