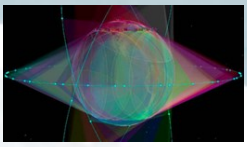





Space Systems facing Commercial and Sustainability Challenges

Opening Lecture for the Brijuni Conference
Brijuni, 29 August,2022

Professor em. Dipl.-Ing. Heinz Stoewer, M.Sc.
President Space Associates GmbH
First Programme Manager Spacelab and Founder Systems Engineering and Programmatics in ESA - ESTEC
Former Managing Director German Space Agency ; Deputy Chair Supervisory Board OHB SE
Emeritus Chair for Space Systems Engineering, Founding Director SpaceTech, Initiator Delfi @ TU Delft
Distinguished Visiting Scientist NASA JPL, Pasadena, California, et. al.
heinzstoewer@spaceassociates.net

1

"Space must not be the Escape Route for Humans from an inhabitable Earth, but an Upgrade to its Civilization"

A wonderful introduction to this conference!

2

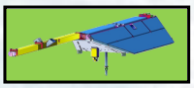
TU Delft

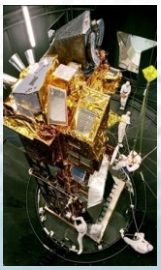
Professional Background

- Studies: Tech. Physics, Bus. Admin., Systems Management, Germany & USA
- Airbus, Space Division Munich, Project Engineer 3rd Stage ELDO Launcher
- Boeing, Systems Engineer Post Apollo Projects, Project Manager Space Tug/OOS
- ESA/ESTEC, 1st Program Manager Spacelab, Founder Sys. Eng. & Progr. Dept
- TU Delft, founding Chair Space Systems Engineering and Director „SpaceTech“
- German Space Agency, Managing Director Programmes, Member ESA Council EU Space Advisory Committee, Chair ESA Programme Board Meteorology & Earth Obs







TU Delft

Current/Recent Activities

- President Space Associates GmbH
- Member Governing Board OHB (Europe's 3rd largest Space Prime contractor)
- Member Sci/Tech Advisory Groups NSO AIRBUS DEFENCE & SPACE
- University Associations TU Delft, Keio University, NUS, Skoltech
- Professional Societies INCOSE *, DGLR, DLR Freunde
- Distinguished Visiting Scientist, NASA-JPL Jet Propulsion Laboratory, California Institute of Technology
- Publications, Books, Editorial Boards, Honors

* Past President, Fellow, Life Member, CTO Vision 2035

My three Topics for Today

- **Astrophysics Observations and long-term Sustainability?**
  - **Satellites and short-term Sustainability?**
  - **Exploration efforts and long-term Human Options?**

Summary and Conclusions

Space Systems facing Commercial and Sustainability Challenges; Keynote for the Brijuni Conference, Croatia, 29 August 2022

5

What an incredible Perspective upon our early Universe

J Webb Telecope July 2022

6

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Some BIG Questions before us

How long will our Planet beLife supporting and livable?

Do we need to explore our Solar System and beyond to ensure Sustainability for future Generations ?

What are our Options for extraterrestrial Settlements ?

7

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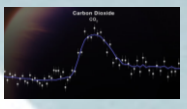
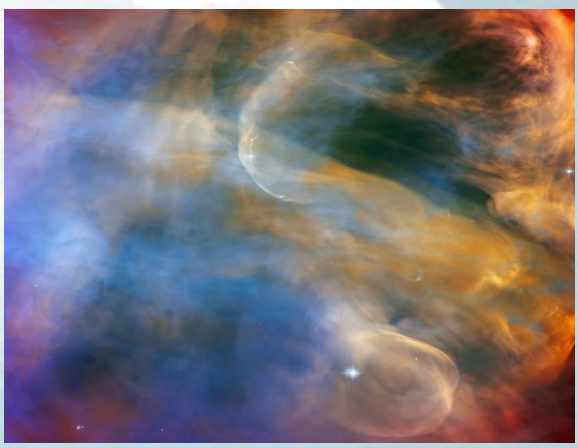
Hubble, James Webb and many other Telecopes depict seemingly infinite number of Objects in our Universe

→ is there Life out there?





8

What did we learn from the Rosetta Mision to Comet 67P/Tschurjumow-Gerassimenko (Churi)?

Recent Data Analyses concluded that Organic (bio)Molecules can travel accross Solar Systems

Examples from a July 2022 Bern University publication:

Prebiotic (intermediate) molecules found, e.g.:

- Sugars and amino acids
- Formamide
- (Water, CO_2, and many more detected earlier)

Fragrant Molecules found, e.g.:

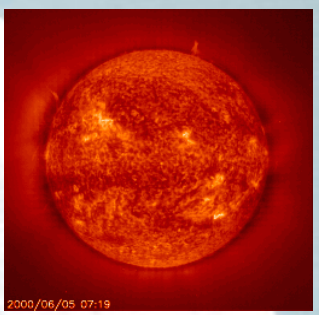
- Naphtalene (mothballs)
- Benzoic acid (incense)
- Benzaldehyde (Almond flavor)

Note: the Hayabusa mission recovered material from asteroid Ryugu and confirmed cross solar system travel of bio material (publication August 2022)

→ **The Chemistry of prebiotic early Earth is (seems to be) the common chemistry of the Galaxy**

(Ref L: Snyder, Univ Illinois)

What then do we know about the Life-Cycle of our Sun?* Will it sustain our Life forever?



- Our Sun is 4.57 B years old. Its life-cycle is similar to other stars. It burns hydrogen to helium for fusion energy
- In roughly 3.5 B years our Sun will reach its max temperature (which is only some 20 deg C higher than the current value of 6045 deg C) and begin to cool, expand and become a „Red Giant“

→ It will then successively destroy the inner planets of our Solar System, incl. our Earth

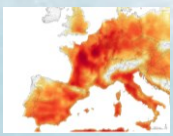
However, this is very far in the future considering that Human life has developed 2 – 6 M years ago and our Planet Earth is only 3.5 B years old

* A July 2022 Astronomy&Astrophysics publication, Creevey et al, analyzed some 5883 stars in an analogous state to our sun

What follows from this Life-Cycle of our Sun?

→ *There is little doubt that we will have to leave our planet sometime in the distant future, the question is only when*

- *This is independent of any other near-term catastrophies (climate, nuclear, asteroid impact, etc) which may force us to seek extraterrestrial refuges much earlier*

What do these Astrophysical Observations tell us ?

- Our Universe is made up of almost infinite „heavenly“ bodies
- Molecules which form the basis of our life (as we know it) seem to be abundently available in space and they seem to travel „boundlessly“ accross our Universe
- Hence we can expect that other places may be habitable, or feature life in some form
- Our Sun, like other stars, has a limited lifetime forcing us eventually to look for other places to live

→ Space exploration is a matter of destiny, sustainability and even of survival!

Space and Sustainability

We need to think in short and long-term Horizons

Long-term for exploring Options of settling on other Places

but also about how to deal with life discoveries somewhere else

Short-term for ensuring this Planet stays livable

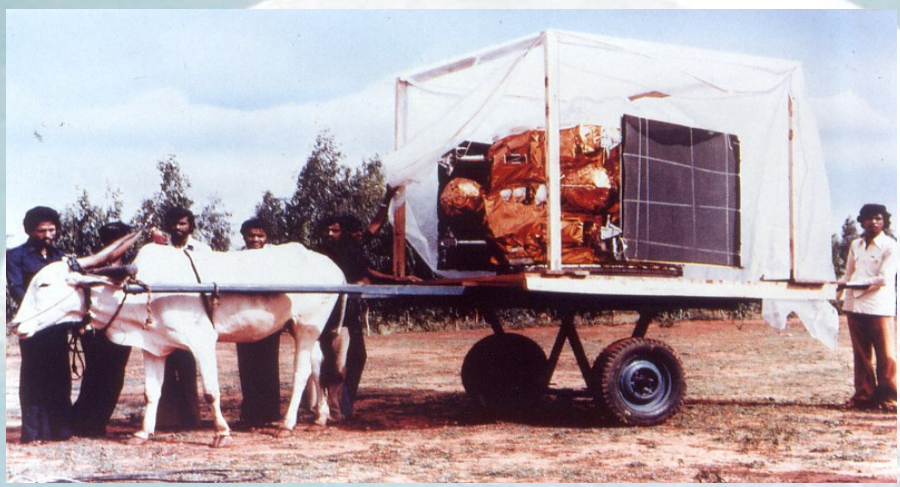
My three Topics for Today

- Astrophysics Observations and long-term Sustainability?
- **Satellites and short-term Sustainability?**
- Exploration efforts and long-term Human Options?

Summary and Conclusions

15

Space has come a long Way!



Some 9000 Satellites launched since Sputnik in 1957

5000 Sats operational today
How many in 2040?

Some 600 Astronauts have been in Space, incl. 250 at the ISS. How many in 2040?

The space sector could grow to 1 - 2 trillion $ by 2040+, or 500 B$ p.y. by 2030 *

Ref.: Stanley Morgan www.morganstanley.com/ideas/investing-in-space

16

The Commercial Space „Explosion“ and „New Space“ have accelerated Satellite Deployments, User Applications, and Launcher Demands

Data is the Gold of the 21st Century, Space is feeding this Gold Rush

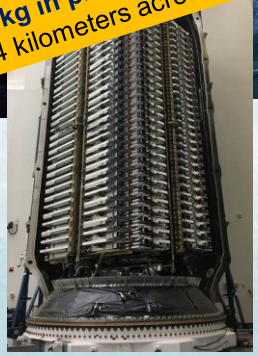
We will launch more Satellites in the coming 10 years than in the 65 years since Sputnik, predominantly for commercial constellations with global reach

17

Example: Starlink Constellation by Space X

Low latency, GB speed direct to home, Sats @ 260 kg each, 250 → 570+ km orbits

- **3100 Sats @ 260kg launched so far, 2800 functioning**
- 2022 Production rate: close to eight+ satellites a day
- **Second generation @ some 1250 kg in preparation;** 29,988 proposed satellites at altitudes of between 340 and 614 kilometers across nine inclined orbits



18

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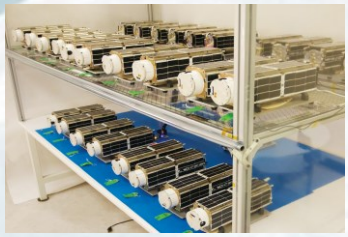
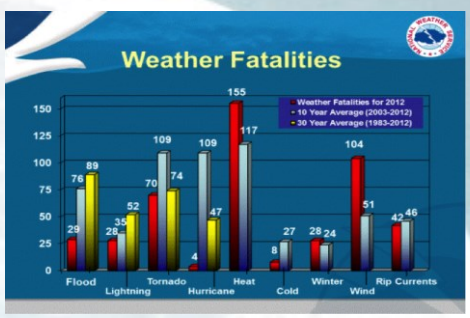
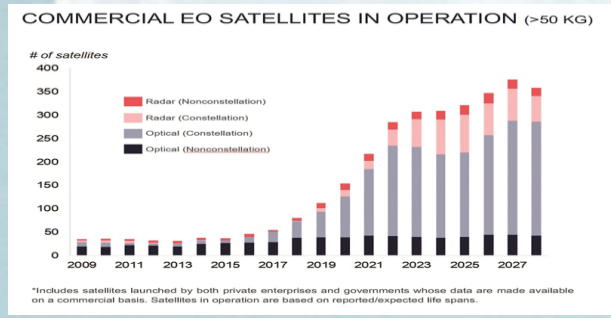
Example: Earth, Weather & Climate Observation Satellites

Example Planet Labs „The entire Earth, every Day" Some 200 Sats in orbit @ 25 terabytes of imagery each day down to 72 cm resolution







We all depend upon precise Weather prediction from big and small satellites

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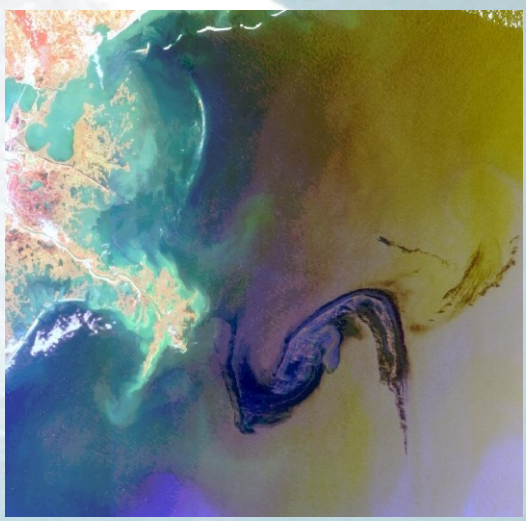
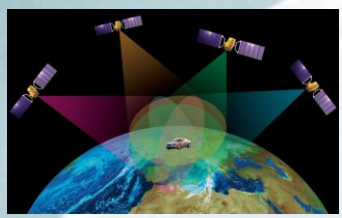
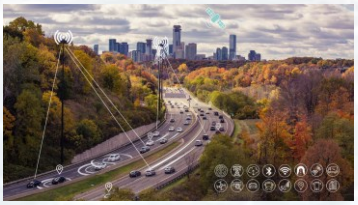
Example: Marine Litter, Oil Spills identified and tracked via Satellites



Example: Navigation & Position Determination from Space

GPS, Galileo, Glonass, Beidou, others address big Variety of Use Cases





Private Investments into Space are „skyrocketing“

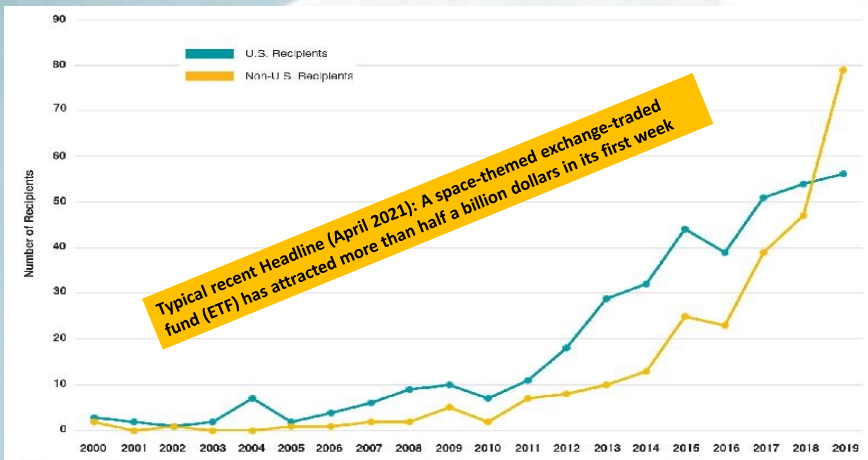


Figure 6. Number of U.S. versus non-U.S. recipients.

@BryceSpaceTech brycetech.com BRYCE space and technology

5.7 B$ in 2019 vs 3.5 B$ in 2018;

70% went to big 4 (Blue Origin, Space X, OneWeb, Virgin Galactic)

135 Startups in total (+34%);

Number of investors +46%, deals +36 %; total invest +61%

79 non US space startups in 2019 vs 47 in 2018

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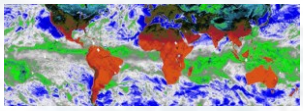
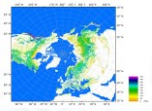
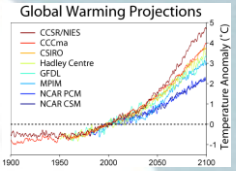
Earth Orbit Services Developments support Sustainability

- **Monitoring our Planet will be BIG Business in the coming years. Every pixel of our Planet will be digitally mapped, "Earth models" will improve by an order of magnitude, predictions of disasters and trends will improve, but climate uncertainties will remain!**

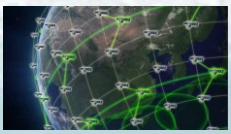




- **Global Navigation Services improvements - incredible Accuracies and Dependability for almost infinite Applications**



- **Affordable Global Communication for 7 Billion People?**
  Big Changes on the Horizon from commercial Space-based Telecommunication Services!





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Military Space – quo vadis?

Mankind is at a juncture on how to tackle military space (even prior to Ukraine conflict)

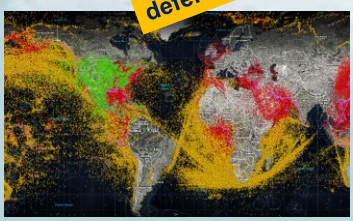
- **Will we follow the 1962/67 UN Resolution/Treaty on the „P…ful Uses of Outer Space"?**
- **Will we reinforce the capability to protect our sp… even attack them?**
- **Are we going to see weapons in space?**

The role of Space will grow substantially! Space and terrestrial defense systems will be increasingly integrated & interoperative



Which approach wi… coming decades?

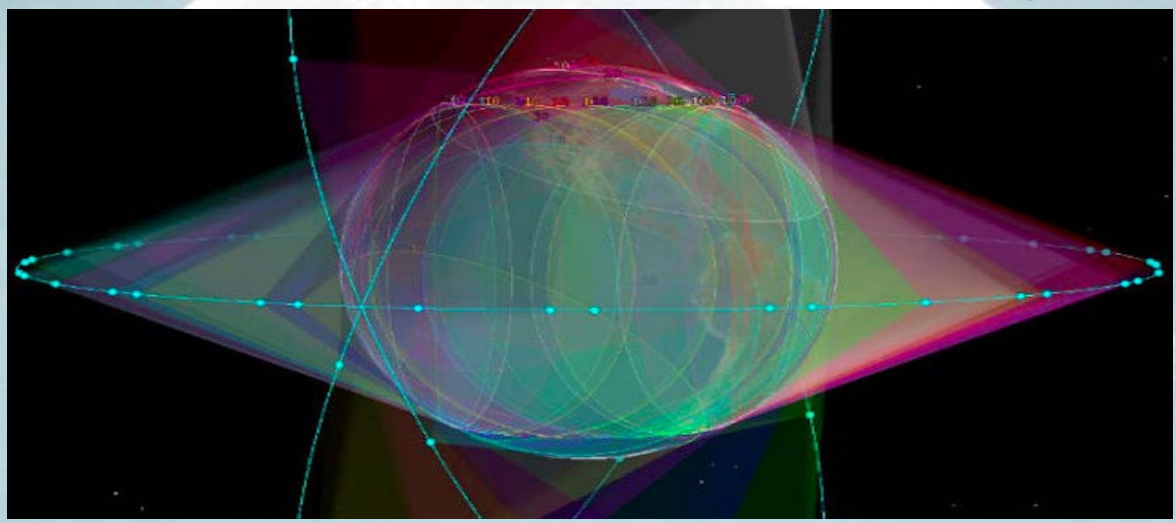
→ Territori… Fear of „potential" enemies? Longing for peace?



The future Satellites Earth Orbit Architecture will be different!

GEO, MEO and LEO will largely merge into a seamless Space Infrastructure and become a growing Asset of a global integrated Earth Information Service Platform

Figure Credit: SES O3B

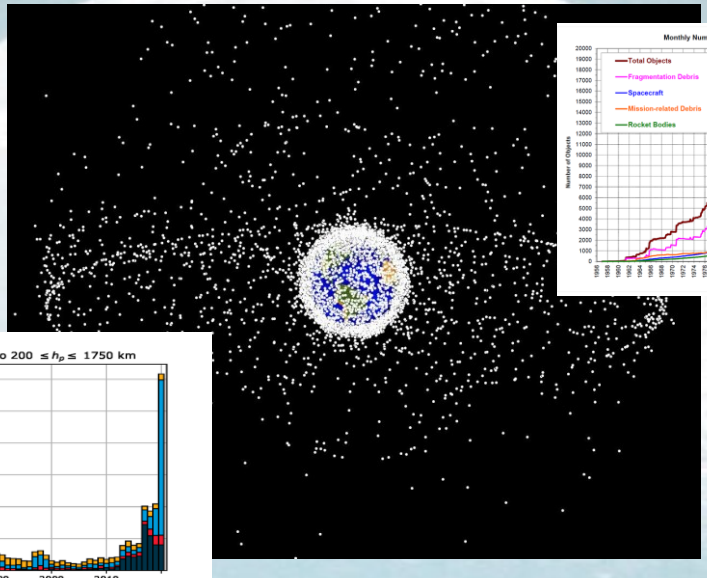


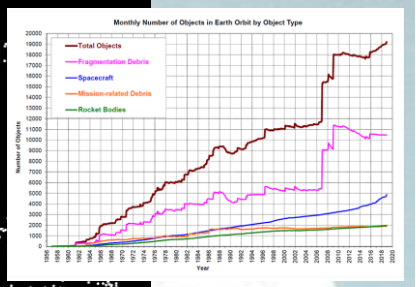
Space Services gradual Integration !

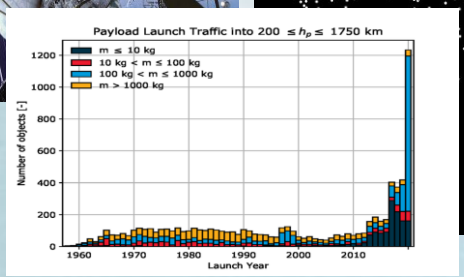
- **Current „stovepipes“ – telecom, navigation, meteorology and Earth observation - will meld largely together into „integrated space services“. Space market shares to grow significantly; terrestrial fibre or submarine cables (@ 30 – 50 k$ per km) can be „out-competed“ in many market segments**
- **Commercial terrestrial and space services will eventually provide one user interface, similar to electricity today (consumers do not care where the energy comes from).**
- **New direct links between satellites and mobile devices will boost acceptance of space services even more**
- **Earth observing data/information will be shared worldwide to help slow the growth of the human footprint and Antropocene impact.**

„Digital Twin Earth“ will make a substantial difference!

But we have also messed up our Earth Orbits with lots of Debris!



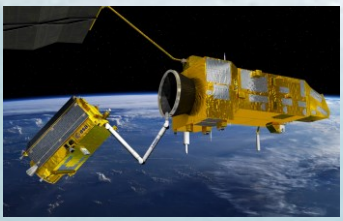




Debris "Market"
Euroconsult forecasts the commercial Space Situational Awareness (SSA) market, combining space and terrestrial systems, will grow from $82 million in 2022 to about $1.4 billion over the next 10 years

To sustain the Space Development we urgently need a global Space Traffic Management Organization à la IATA with Functions like:

- Ensure safe traffic and mitigate collision risks
- Approve space launches based upon global policy framework and clear criteria
- Register and track every satellite and piece of debris
- Make information publicly available
- Impose penalties upon non-cooperative operators
- Etc. etc.



So do (Commercial) Satellites and Sustainability really fit together?

35

The United Nations 17 Sustainable Development Goals

a Proxy for near-term Human Needs

Can Space Systems contribute?

36

The UN „Space2030“ Agenda
Space is a Driver of sustainable Development

Three quotes from the UN General Assembly Resolution of 25 October 2021

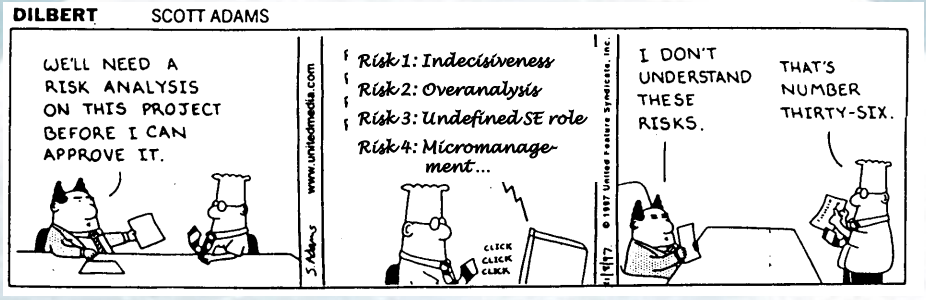
- Space science and technology are now intrinsic to our daily life on Earth and bring an abundance of unique and fundamental benefits to Earth
- We emphasize that space tools are highly relevant for the attainment of the global development agendas, in particular the 2030 Agenda for Sustainable Development
- … space science and technology and their applications are contributing immeasurably to economic growth and improvements in the quality of life worldwide

Would the UN Paris and Glasgow et al global conferences on World Climate Evolution, Desertification, and more have been possible without long-term data from Space?

A couple of passing Remarks upon „New Space“

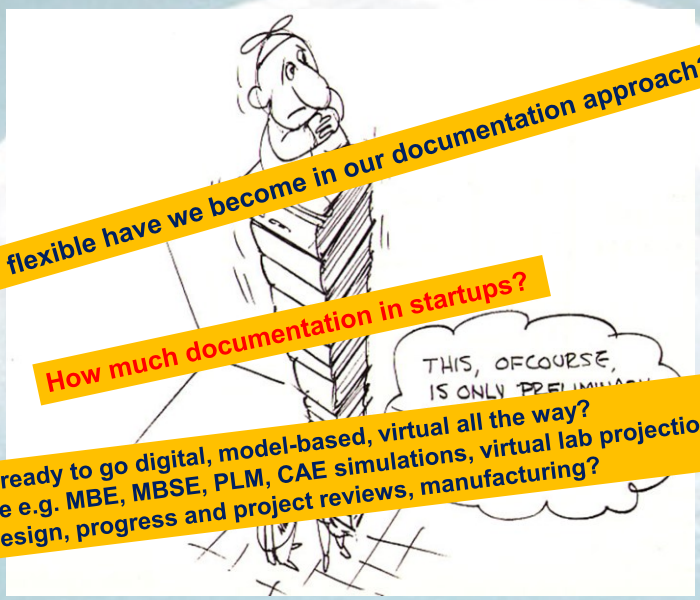
- **High Risk preparedness is key; failure is part of the business equation**
- **„Ilities“ are circumvented, e.g. by buying simple satellites and planning some 20 to 30 % spares as in-orbit, or on-ground replacements**
- **Every decision mirrored against business opportunity, not cost**
- **Flat hierarchies, fast decisions, empowerment of teams and „minimal“ controlling**
- **Max digital operations, software emphasis and minimal documentation**
- **→ relatively more easily applied to small satellites and applications, not (yet) to „complex“ one-off spacecraft**

Largest difference between public funded and "New Space" projects lies in how they treat Risks



With minor modification by KJF

If America wants to succeed, it needs to learn to fail (again)
(Gen. John Hyten, Head of U.S. Strategic Command, June 2017)
"We've lost the ability to go fast, test, and fail. We tie the hands of our engineers and acquisition folk because we expect every test to work and if it doesn't work it's on the front page of the newspaper. We have got to get back to where we accept risk."



How flexible have we become in our documentation approach?

How much documentation in startups?

Are we ready to go digital, model-based, virtual all the way? …where e.g. MBE, MBSE, PLM, CAE simulations, virtual lab projections drive design, progress and project reviews, manufacturing?

Another big difference between "new" and "classical" space could be documentation ?

My three Topics for Today

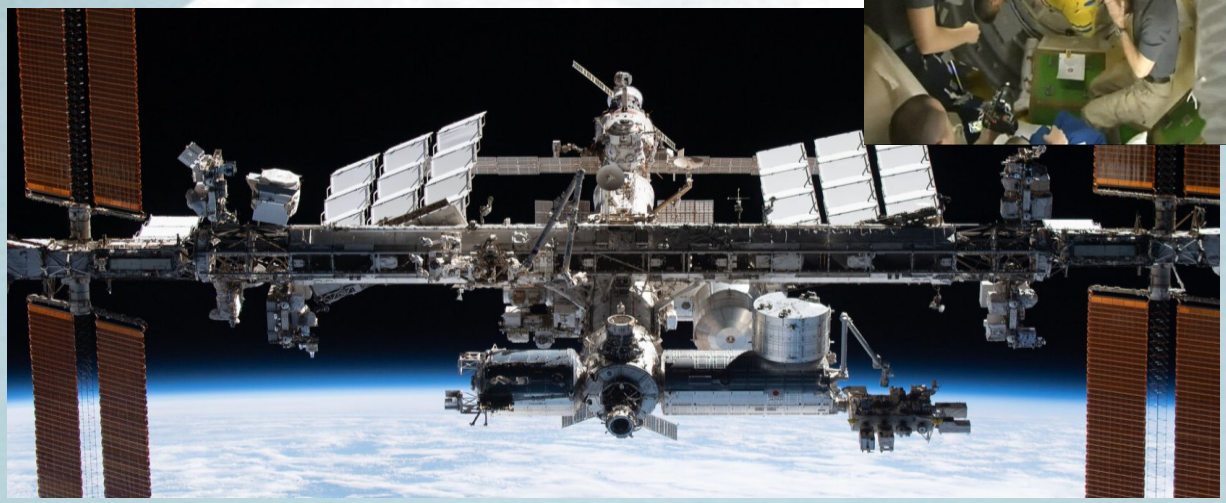
- Astrophysics Observations and long-term Sustainability?
- Satellites and short-term Sustainability?
- **Exploration efforts and long-term Human Options?**

Summary and Conclusions

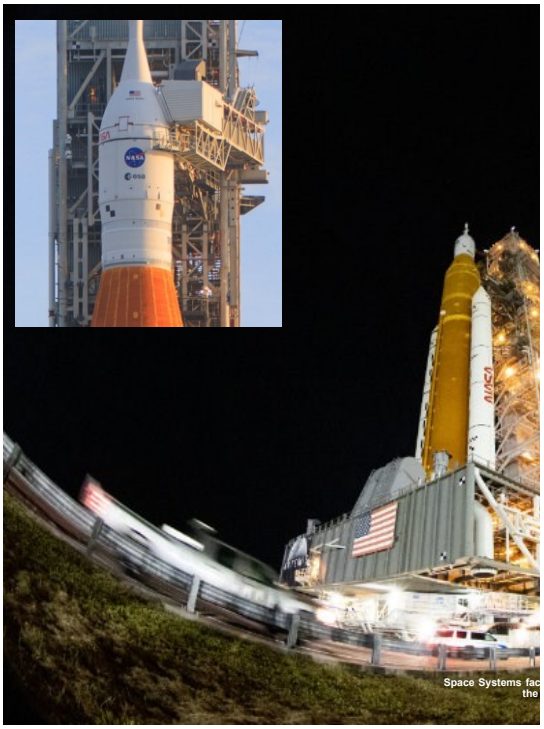
41

ISS – Pathfinder for Life in Space and more!

Disposal by 2030/31!? Disintegration earlier?



42



SLS and Artemis Mission Nr 1

Back to the Moon and on to Mars sometime in the 30s or 40s

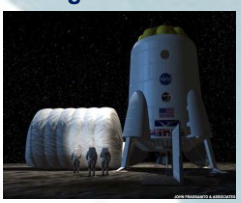
ALERT
Artemis 1 launch scheduled for today at 14.33 our time

43

Artemis with Orion Capsule, European Service/Propulsion Module

Artemis III South Pole Landing Options

… and then on to landing on the Moon



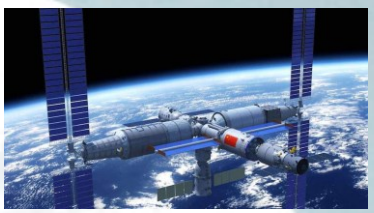
Space Systems facing Commercial and Sustainability Challenges; Keynote for the Brijuni Conference, Croatia, 29 August 2022

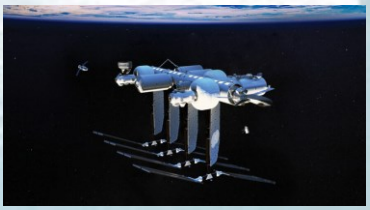
44

Space Station Scenarios post 2030

- US wants to „commercialize“ Human Spaceflight in LEO
- China, Russia, India likely to have/retain Space Stations
- What will be Europe‘s Posture?
  - buy an appartment in a Chinese or US commercial station?
  - build a European space station? With a re-usable launcher?
  - and possibly operate it together with other nations?

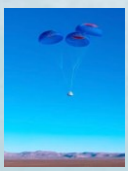
→ can we muster sufficient political will and funding?





Space Tourism?

- Likely to follow the Aircraft and Zeppelin examples of some 100 years ago
  → human curiosity and sense of adventure are overwhelming! Money is not the issue!
- Ballistic and orbital tourist flights will become routine, despite risk and cost;
  LEO hotels likely!
- Lunar tourism to remain limited – complex, risky, very expensive!
- Reusable „flying“ return vehicles will replace capsules! Dual use technology with hypersonic terrestrial aircraft?



New reusable US (and Chinese) Space Transportation Systems

From „small to huge“, return Capabilities, orbital Tugs – tomorrows Benchmarks?

New Glenn

Starship

SLS for Artemis

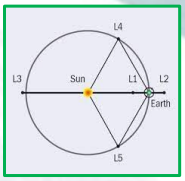
Ariane 6 ?

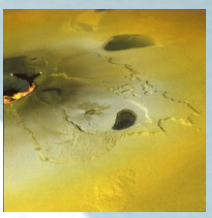
Orbital Service Vehicle

Reusable Launch/Reentry Vehicle Concepts

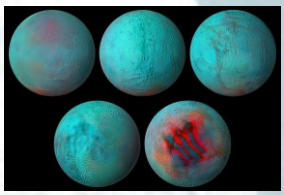
Neutron

Our Options for future Human Settlements?

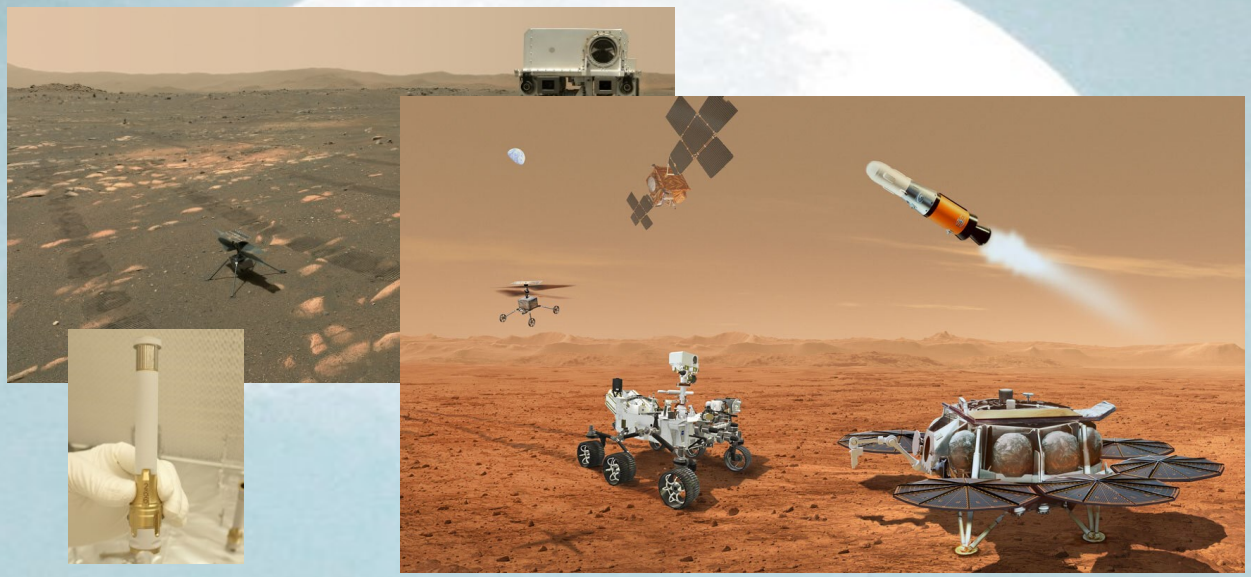




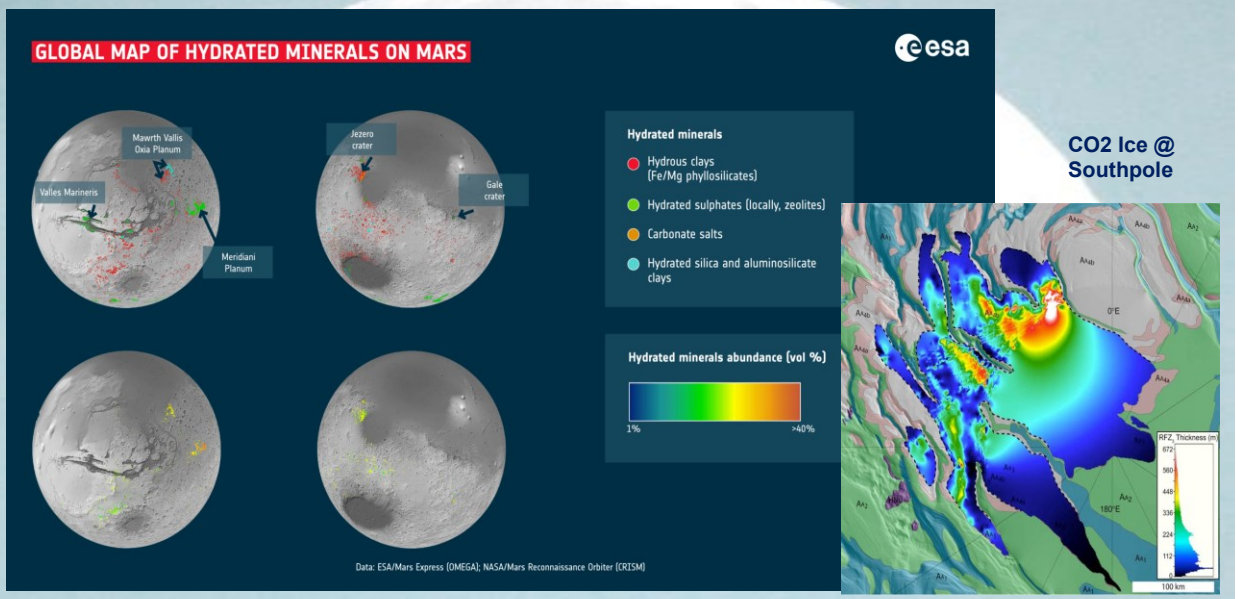
- Lagrange Points L4 and L5
- Moon, as stepping stone for Mars
- Jupiter Icy Moons Europa, Ganymede, Io, Callisto, others?
- Saturn Moons, notably Titan, may be Enceladus, others?
- Outer Planets in a second wave?
- Exoplanets (beyond our Solar system), to be determined in the coming decades!



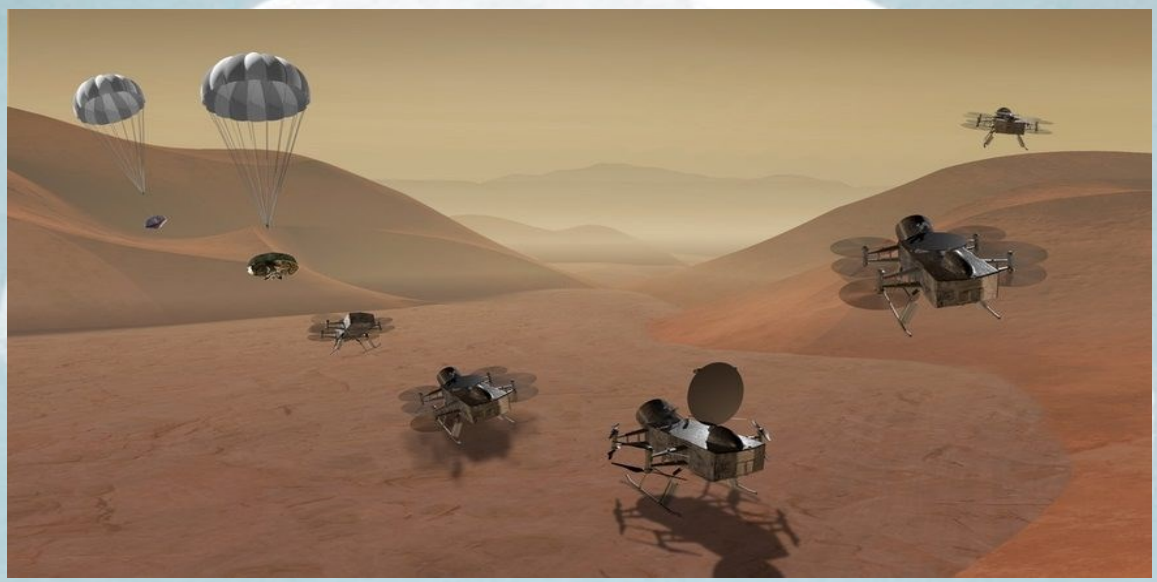
A precursor Mission: Perseverance Rover, Ingenuity helicopter, European Return Vehicle for the Mars Sample Return Mission



Water Map of Mars – how well would Mars support Life?

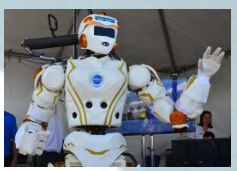


Example: Dragonfly Mission (with Rotorcraft) to Titan late 2030s?



We need a "balanced" affordable Exploration Approach?

- What kind of balance between robotic and human exploration?
  …. in view of advancing sensor, processing, AI,
  & communication technologies, limited budgets?



- Lunar Exploration could become routine if the political support remains unwavering - but will remain risk prone!

- Human missions to Mars need faster propulsion, human genetic adaptations, and a step by step approach, à la Apollo/Artemis!
  → One-way travel or Mars Colonies should be disallowed!! Such missions are unethical until we have safe two-way transportation and a local infrastructure in place – not by 2040!

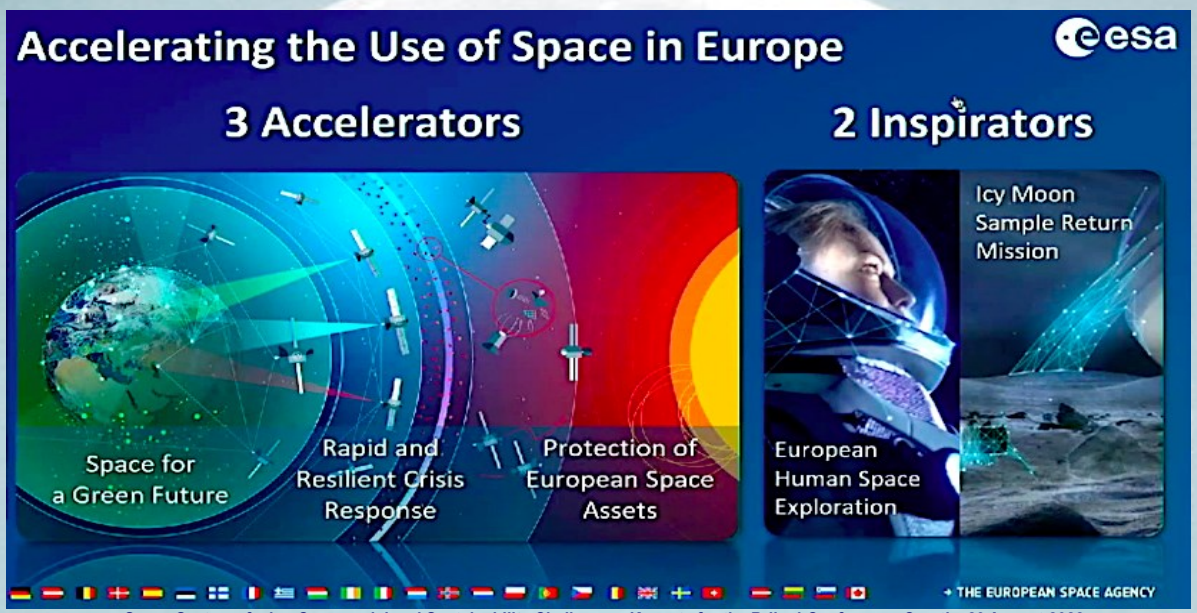
PS: Commercial prospects for Moon and Mars exploration are limited, but is this important?

How should Europe deal with Moon and Mars?

- Should we continue to cooperate with the US and others, remain junior partner? Fly our astronauts with other nations?
- Should we focus more upon robotic and science missions?
- What could be a good compromise between cooperation and independance?

We need a political debate to find our European answers to above and more!

ESA „Agenda 2025“ - great Ambitions and some Anwers!



During two interrelated ESA an EC Ministerial Space Summits, Feb 2022, in Toulouse the following Decisions were taken

- European Commission projects related to implementing an EU constellation for connectivity
- Defining common rules governing space traffic management
- EU roadmap regarding Earth and climate observation from space
- Europe's objectives in terms of science and space exploration

→ An ESA Ministerial Council scheduled 22/23 Nov 2022 in Paris should advance several new initiatives and funding for next 3 years

→ European Human Spaceflight at a later tbd meeting

What we would need is Star Trek - will it ever realize?

My three Topics for Today

- Astrophysics Observations and long-term Sustainability?
- Satellites and short-term Sustainability?
- Exploration efforts and long-term Human Options?

Summary and Conclusions

57

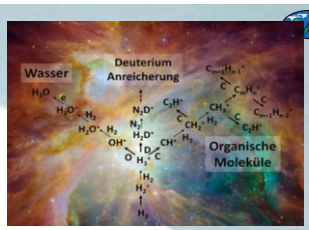
Can the „Green Deal“ work without Space Contributions? Without Commercial Space?

- The Paris, Glasgow and other global UN conferences and agreements without Space?
- Energy transition without Space? Without solar cells, fuel cells and hydrogen know-how acquired over decades? Without the „end-to-end“ systems competence of space?
- Automated driving without safe/accurate navigation and communication from space?
- Etc. etc.

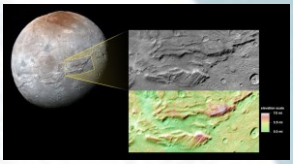
→ The Green Deal and our Planet‘s Sustainability need Space

58

Space Exploration



- Lots of fascinating robotic missions underway and planned, e.g. JWST, Clipper and Juice to Europa and Jupiter Moons, several „Astrophysics“ missions
- Artemis as great Human venture about to start
- Cina, India strongly invest into Human spaceflight, incl. Moon and Mars
- Europe has excellent robotic missions; destiny for Human spaceflight remains tbd



Final Philosophical Thoughts

Our Human Outpost in Space works admirably well despite political Upheavels!

Why can we not work together on Earth as we can in Space?

Final Philosophical Thoughts

Do we need an extraterrestrial Threat to understand our responsibility for managing and preserving this Planet?

Who knows what kind of life may be out there?

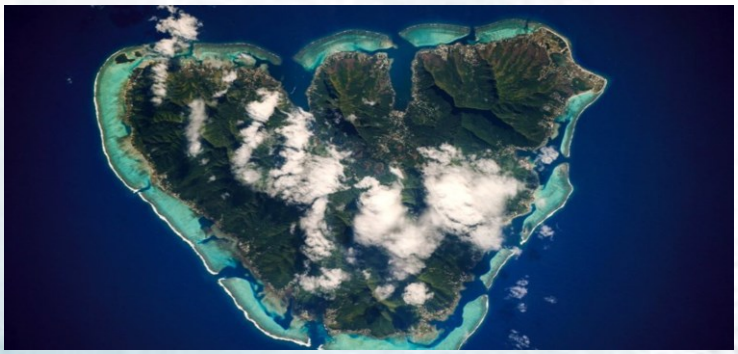
If we Earthlings will not be united and prepared for the discovery of extraterrestrial life, what will happen?

My Messages to you, the young Generation and Students

1. *Continue to activate the Path of Sustainability anywhere*
2. *Make Space an overarching peaceful Tool for managing our Planet*
3. *Help build a strong and independent Europe - able to decide upon our own Destiny*

PS: Space offers almost infinite Opportunities for professional Growth and personal Satisfaction

Thanks for your Attention !



Morea / Tahiti

Let's take good care of this Planet – we do not (yet) have a second one!