News Feature: The 2021 ISU Masters Elective and Masters Projects

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This year the International Space University and i4is have again offered a two week interstellar elective to students taking Masters of Space Studies (MSS) at ISU. A number of ISU students have also completed substantial studies on interstellar topics with the support of i4is experts. Here we summarise this year's work.

Interstellar Elective

As before, the elective consisted of one week of presentations by i4is and other experts as introduction to substantial assignment course work on this year's topic, Worldships -

- Professor Chris **Welch**
- Rob **Swinney**
- John **Davies**
- Dr Andreas **Hein**
- Olivia **Borgue**
- Michael **Madsen**
- Dr Frédéric **Marin**
- Michel **Lamontagne**
- Simone **Caroti**
- Dr Dan **Fries**

Presentations and videos are available in the members area of the i4is website. The programme -

	Monday 26 April	Tuesday 27 April	Wednesday 28 April	Thursday 29 April	Friday 30 April
9:00 to 10:00	M8-ISR-L01 Introduction to Elective + Interstellar Studies	M8-ISR-L05 Precursor Missions + Destinations	M8-ISR-L09 Advanced Propulsion Systems 1	M8-ISR-L13 The Case for Interstellar	M8-ISR-L17 Our Interstellar Future
	Welch/Swinney	Swinney	Swinney	Welch	Davies
10:15 to 11:15	M8-ISR-L02 Introduction to Worldships	M8-ISR-L06 Worldship Systems	M8-ISR-L10 Advanced Propulsion Systems 2	M8-ISR-L14 Worldship Documentary	Group Meeting
	Hein	Hein	Borgue	Madsen	
11:30 to 12:30	M8-ISR-L03 Introduction to Assignment	M8-ISR-L07 Artificial Intelligence for Worldships	M8-ISR-L11 Worldship Population Dynamics	M8-ISR-L15 Interstellar Missions and Concepts	Assignment work
	Hein	Davies	Marin	Swinney	
14:00 to 15:00	M8-ISR-L04 Worldship Design 1	M8-ISR-L08 Worldship Design 2	M8-ISR-L12 Worldships in Science Fiction	M8-ISR-L16 Advanced Propulsion Systems 3	Assignment work
	Lamontagne	Lamontagne	Caroti	Fries	

Assignment work took up the remainder of each day in this first and the whole of the following week with students presenting their results on Thursday 6 May. We'll be reporting on the results of the course work in the next issue of Principium.

Studies on Interstellar Topics

The topics suggested for substantial investigation by MSS students were developed by Dr Andreas Hein (Initiative for Interstellar Studies). Professor Chris Welch (International Space University) and Rob Swinney, i4is Director of Education.

All of these are likely to be entered for peer-reviewed publication and we will, of course, report further when they are published.

McKendree world ship

A McKendree cylinder is an upscaled version of an O'Neill colony with a length of 4,600 km and a radius of 460 km, introduced by Tom McKendree. Its internal surface area is roughly the size of Russia. It is, therefore, considerably larger than the largest O'Neill colonies (length ~30 km) and world ship habitats (~200 km). The goal of this project is to assess, if a world ship based on a McKendree cylinder could be built (eg required propellant mass, propulsion system) and if yes, to propose a high-level conceptual design for a McKendree world ship.

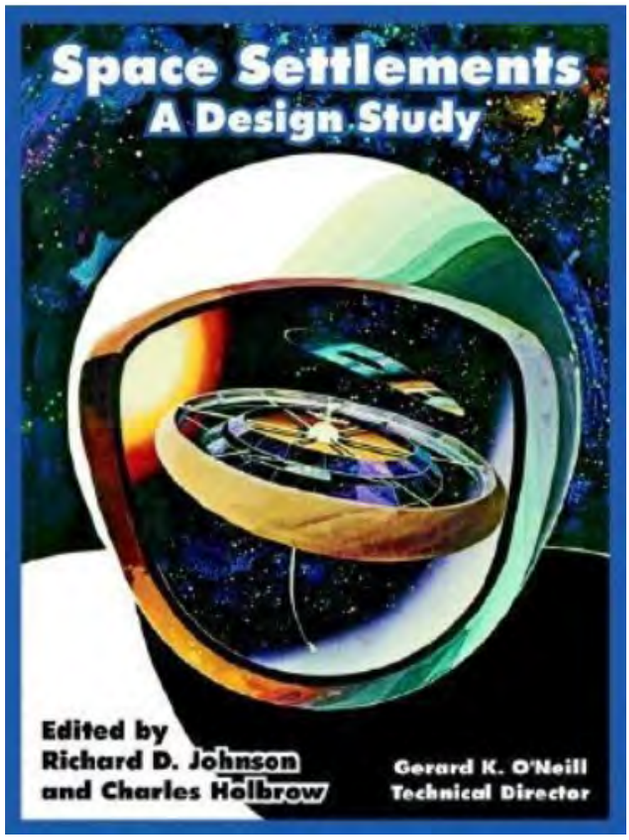
References:

en.wikipedia.org/wiki/McKendree_cylinder

Implications of Molecular Nanotechnology Technical Performance Parameters on Previously Defined Space, System Architectures, Thomas Lawrence McKendree, 1995 www.zyvex.com/nanotech/nano4/mckendreePaper.html

Hein, A M, Pak, M, Pütz, D, Bühler, C, & Reiss, P (2012). World ships—architectures & feasibility revisited. Journal of the British Interplanetary Society, 65(4), 119. www.researchgate.net/profile/Andreas-M-Hein/publication/236177990_World_Ships_-_Architectures_Feasibility_Revisited/links/0c960516e5549a8b41000000/World-Ships-Architectures-Feasibility-Revisited.pdf

Bond, A, & Martin, A R (1984). World ships-an assessment of the engineering feasibility. Journal of the British Interplanetary Society, 37, 254.



Cover of *Space Settlements: A Design Study*, Richard D Johnson, Gerard K O'Neill, University Press of the Pacific, 2004. Report of a 10-week program in engineering systems design held at Stanford University and the Ames Research Center of the National Aeronautics and Space Administration during the summer of 1975. Cited by McKendree.

Do we need space settlements as precursors for world ships?

World ships contain large habitats in which its inhabitants need to survive over centuries. In order to minimize risk for the inhabitants, it may be expected that such habitats have already been tested over extensive durations within our solar system. This has been proposed, for example, by Gerard K O'Neill. A more recent assessment on what can and cannot be proven via a space habitat in our solar system regarding a world ship has been provided by Hein et al. (2012). The objective of this project is to revisit this assessment and to extend it to planetary surface settlements, to provide a wider picture of how space habitat heritage can be accumulated within our solar system.

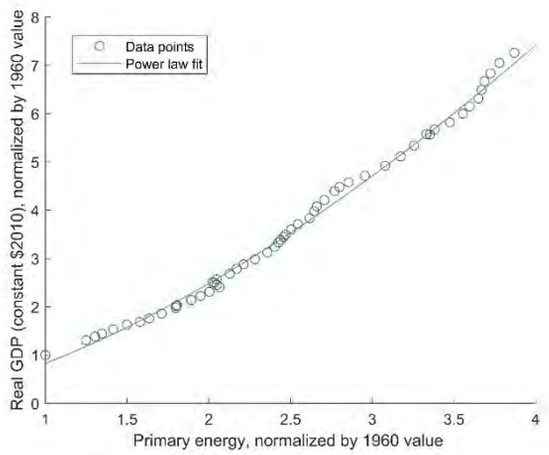
References:

Hein, A M, Pak, M, Pütz, D, Bühler, C, & Reiss, P (2012). World ships—architectures & feasibility revisited. Journal of the British Interplanetary Society, 65(4), 119. www.researchgate.net/profile/Andreas-M-Hein/publication/236177990_World_Ships_-_Architectures_Feasibility_Revisited/links/0c960516e5549a8b41000000/World-Ships-Architectures-Feasibility-Revisited.pdf

O'Neill, G K (1977). The High Frontier: Human colonies in space.

Economic preconditions for building world ships

A world ship requires an economy which is much larger than the currently existing one. At current growth rates of global wealth, expressed via the Gross Domestic Product (GDP), a world ship might become feasible in the year 2300 to the year 3000. However, GDP growth over such extended periods are expected to be problematic, due to energy limits (Hein & Rudelle, 2020) and their environmental impact in general. The objective of this paper is to assess various scenarios, for example, from Hein & Rudelle (2020) and their implications for the economic feasibility for world ships. An interesting conclusion from this research might be the first quantitative demonstration that world ship-type projects can only be realized via an in-space economy.



Data points for normalized world primary energy generation versus constant $2010 GDP from 1960 to 2015 and power law fit. Figure 1 from Hein/Rudelle (2020), Energy Limits to the Gross Domestic Product on Earth

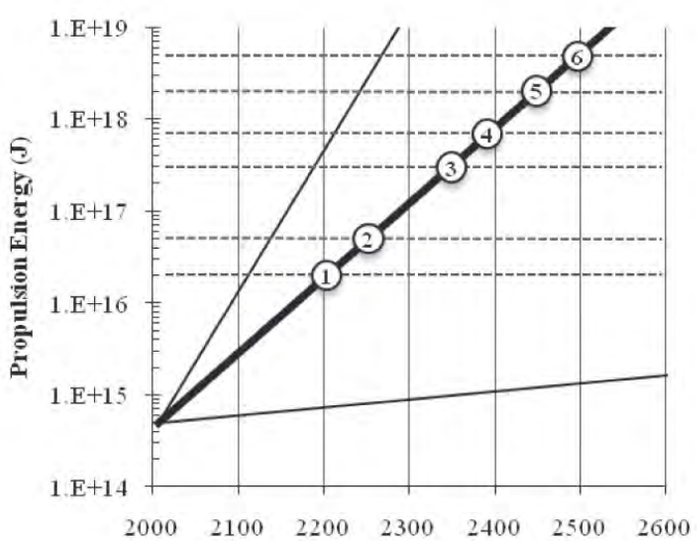
References:

Hein, A M, & Rudelle, J B (2020). Energy Limits to the Gross Domestic Product on Earth. arXiv preprint arXiv:2005.05244. arxiv.org/ftp/arxiv/papers/2005/2005.05244.pdf

Hein, A M, Smith, C, Marin, F, & Staats, K (2020). World ships: Feasibility and Rationale. arXiv preprint arXiv:2005.04100. Specifically Section 7. zenodo.org/record/3747333#.YISRVaE6_IU

Martin, A R (1984). World Ships-Concept, Cause, Cost, Construction and Colonisation. Journal of the British Interplanetary Society, 37, 243.

Millis, M G (2010). First interstellar missions, considering energy and incessant obsolescence. JBIS, 63, 434-443. www.researchgate.net/profile/Marc-Millis/publication/280742055_First_interstellar_missions_considering_energy_and_incessant_obsolescence/links/55c5164208aea2d9bdc39806/First-interstellar-missions-considering-energy-and-incessant-obsolescence.pdf



Correlation between growing propulsion energy availability (bold line) and energy thresholds (dashed horizontal lines). The narrower sloped lines represent ±1 standard deviations of growth. Based on the data shown in Tables 1, 2 and 4 the numbered intersections refer to these events: 1. Colony ship (10^7 kg) kinetic energy threshold reached, 2. Propulsion energy available when humanity achieves the equivalent of 100% of sunlight on the Moon (5 x 10^{16} J), 3. Centauri probe (10^3 kg) kinetic energy threshold reached, 4. Propulsion energy available when Kardashev Type I status attained (7 x 10^{17} J), 5. Centauri probe (10^3 kg) rocket energy threshold reached, 6. Colony ship (10^7 kg) rocket energy threshold reached. Figure 1 from Millis(2010)

Manufacturing infrastructure for world ships

Bond and Martin (1984) propose various manufacturing technologies for constructing a world ship. However, the infrastructure for manufacturing a world ship will be enormous and includes an entire supply chain, starting from resource extraction, processing, to component manufacturing, and assembly. The objective of this project is to map out the different steps of the infrastructure that is capable of manufacturing a world ship and proposing different technology alternatives for each step. If possible, high-level estimates for the capacities of each step should be provided,

References:

Bond, A, & Martin, A R (1984). World ships-an assessment of the engineering feasibility. Journal of the British Interplanetary Society, 37, 254.