

K-Town: Portrait of a Thousand- Person Colony on Mars



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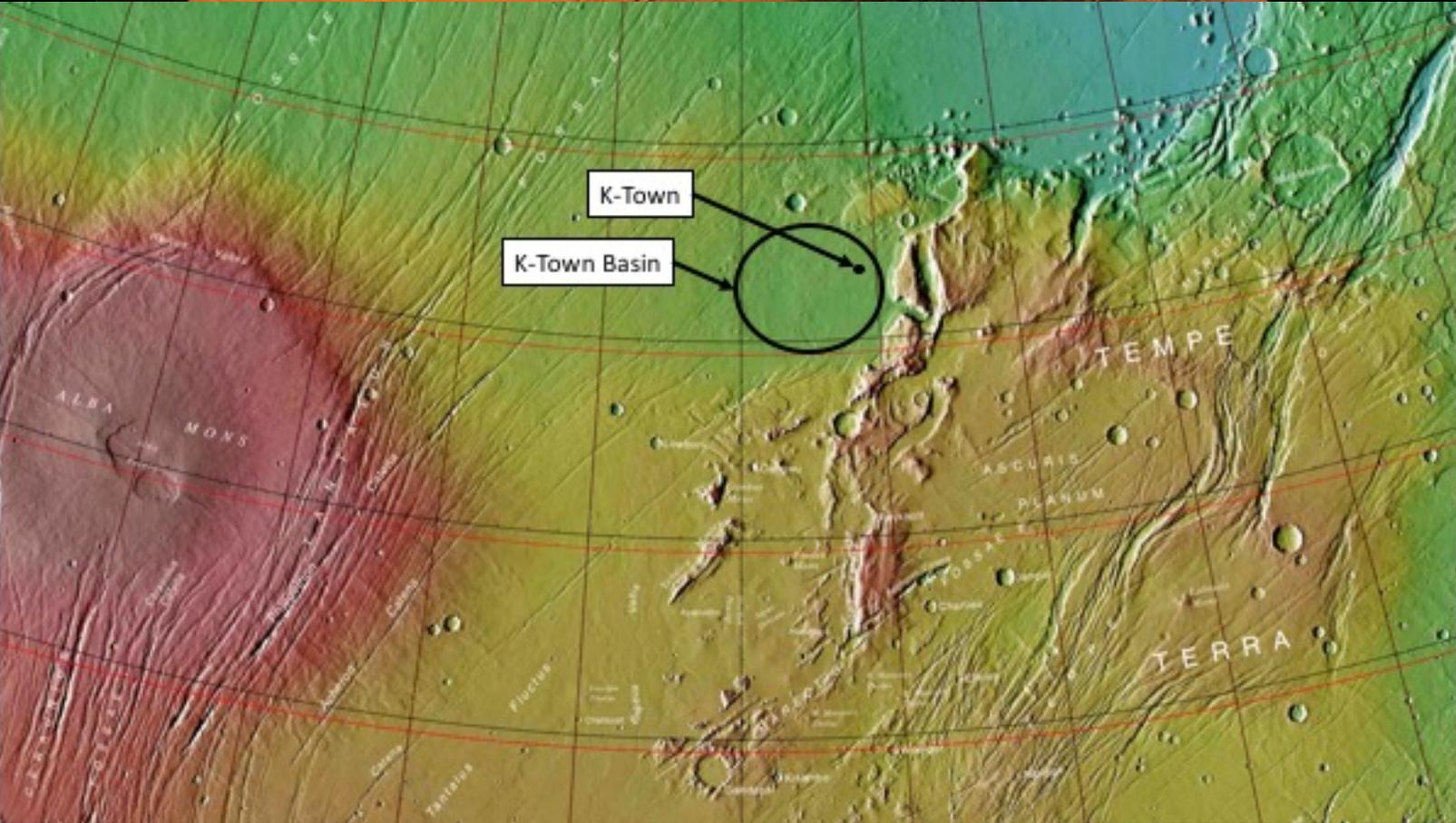
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Space Resources Roundtable and Planetary and Terrestrial Mining Symposium
Golden, CO June 11-15, 2019

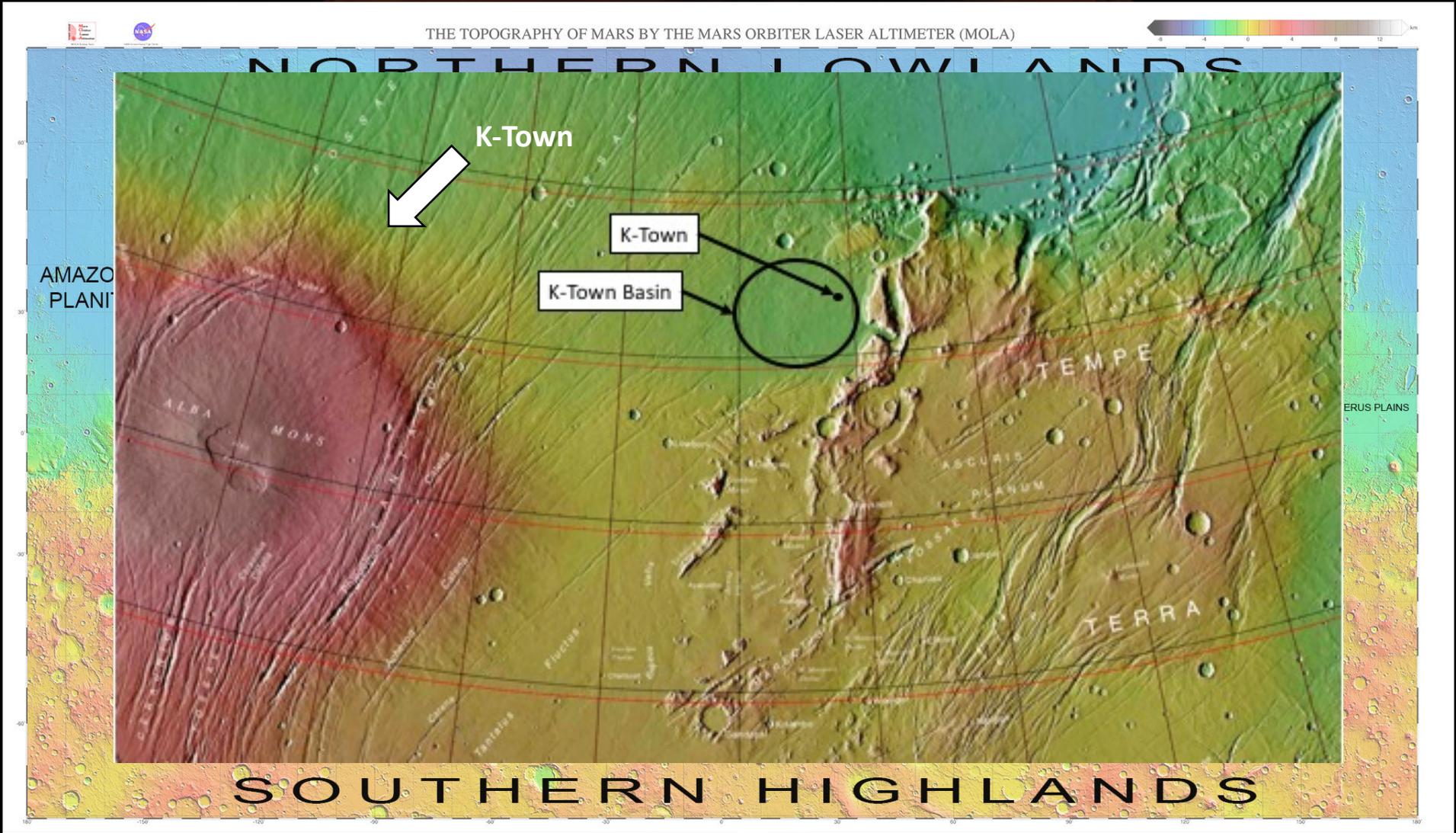
Background and Motivation

- Response to the Mars Society's 2019 Mars Colony Prize
- Emerging Futures has been modeling various aspects of large-scale human settlement since 2015
- Opportunity to focus on a concrete goal with explicit assumptions
- Utilizes ASTER, a resource modeling tool developed in-house
- Told from the perspective of 2049, in the colony's 10th M-year
- Submitted March 31, 2019 in collaboration with Akhil Rao, Ph.D.
- Emerging Futures chosen as a semi-finalist in May!
- If selected for final round, will present in person in October

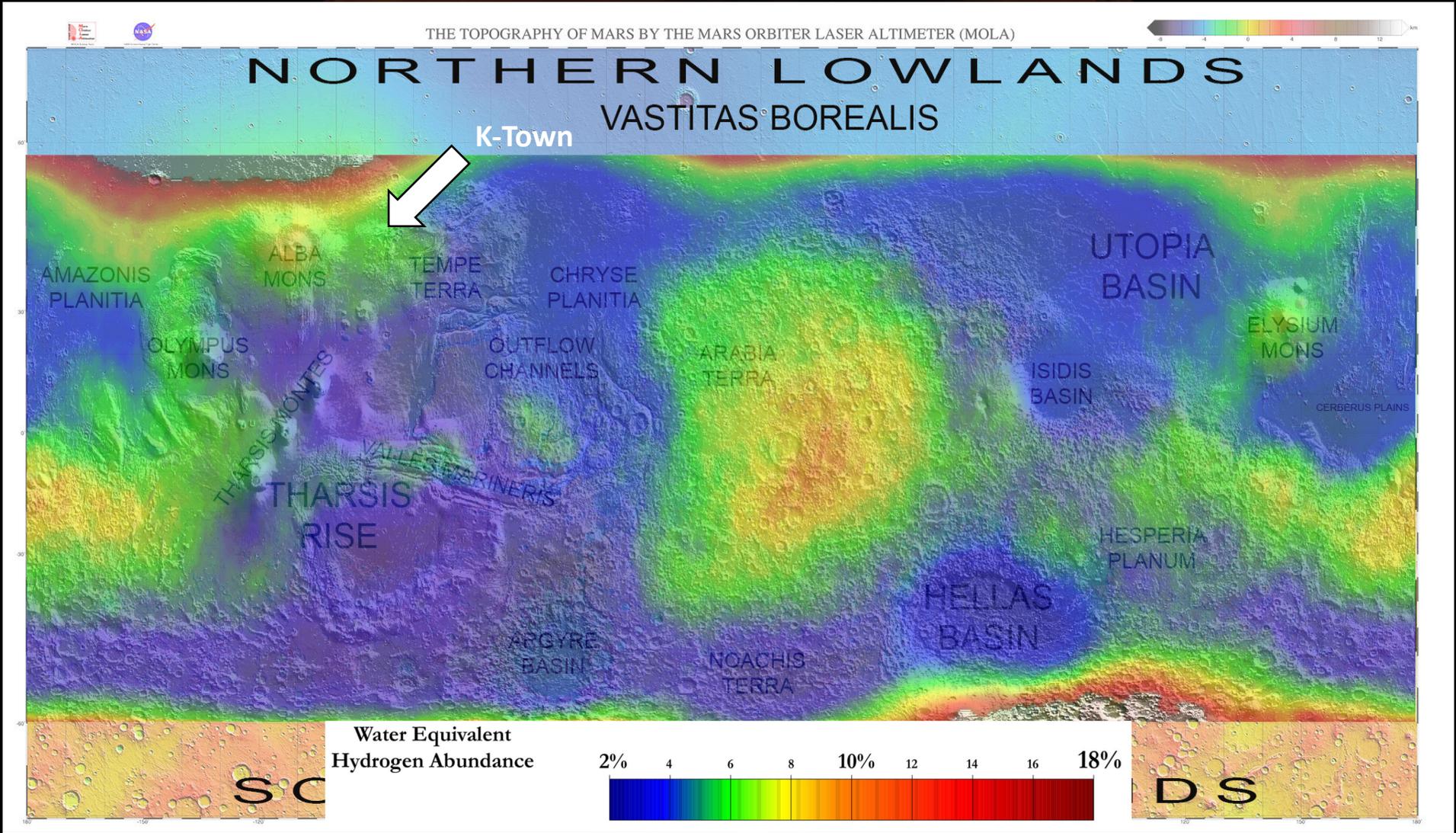
Welcome to K-Town!



Welcome to K-Town!



Located near abundance of subsurface water



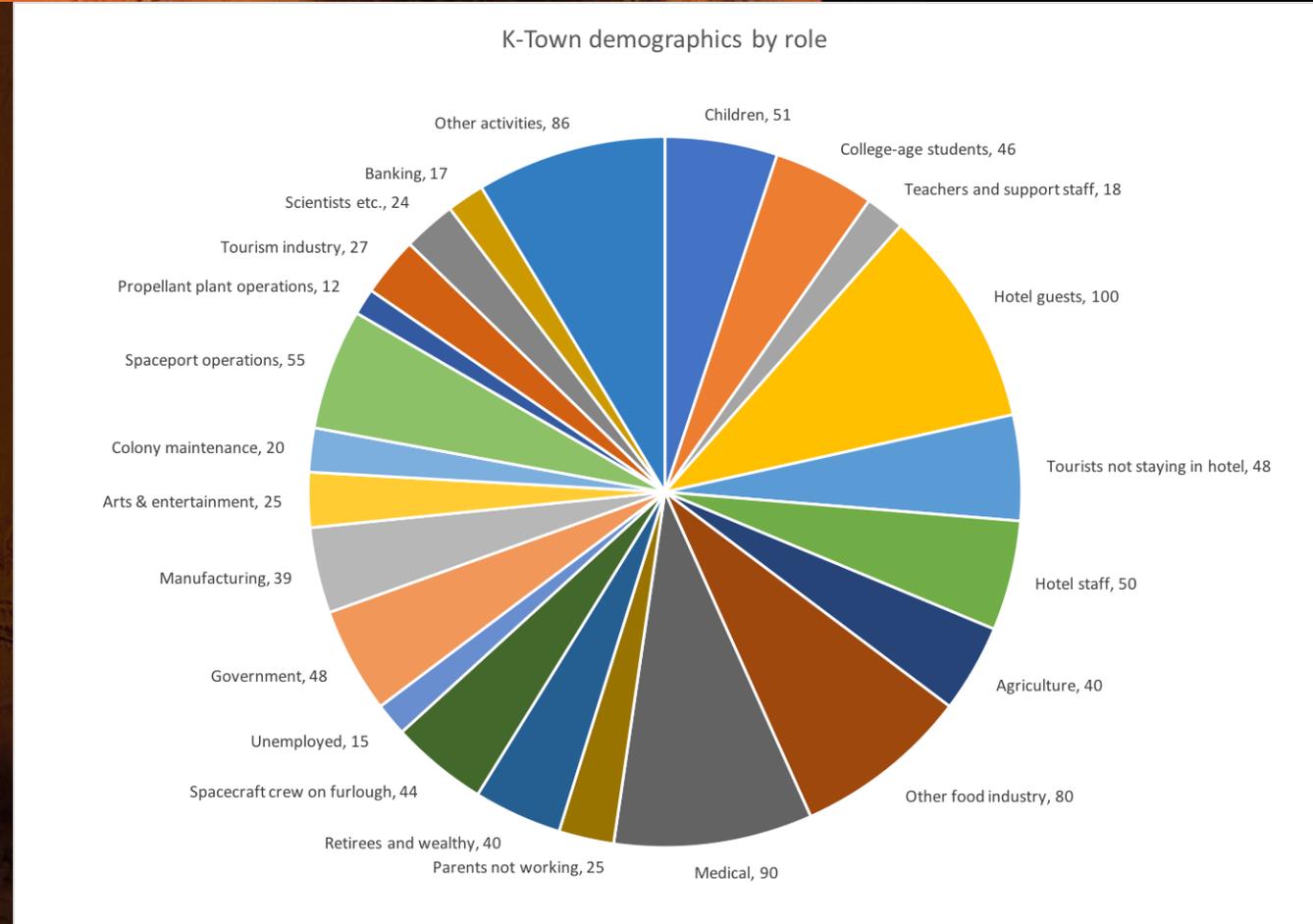
Assumed demographics

393 total visitors:

- Professionals: 204
- Tourists: 96
- Spacecraft crew: 44
- Other Martians: 26
- Exchange students: 23

Change per synod (2.14 E-years):

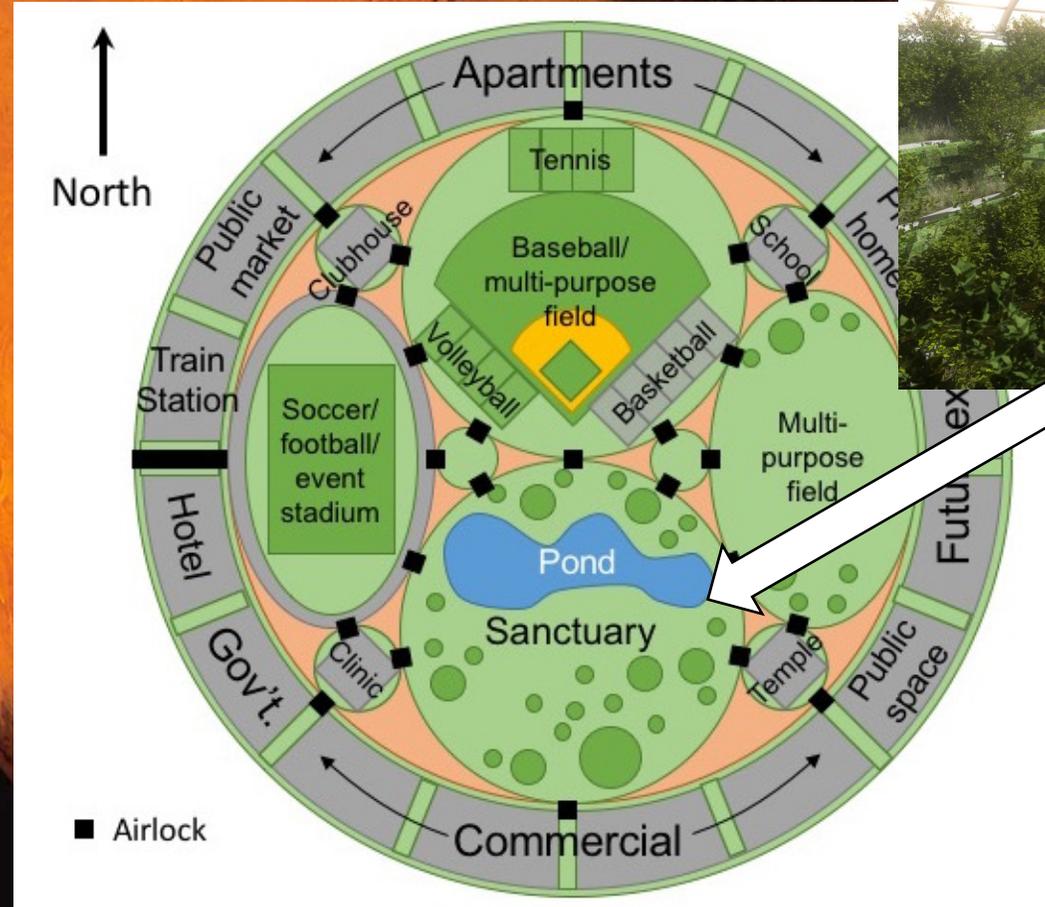
- Births: 5
- Deaths: 7
- Immigrants: 209
- Emigrants (to Earth): 50
- Net growth: 157 (7.1%/E-yr.)



Based on U.S. census data (with modifications)

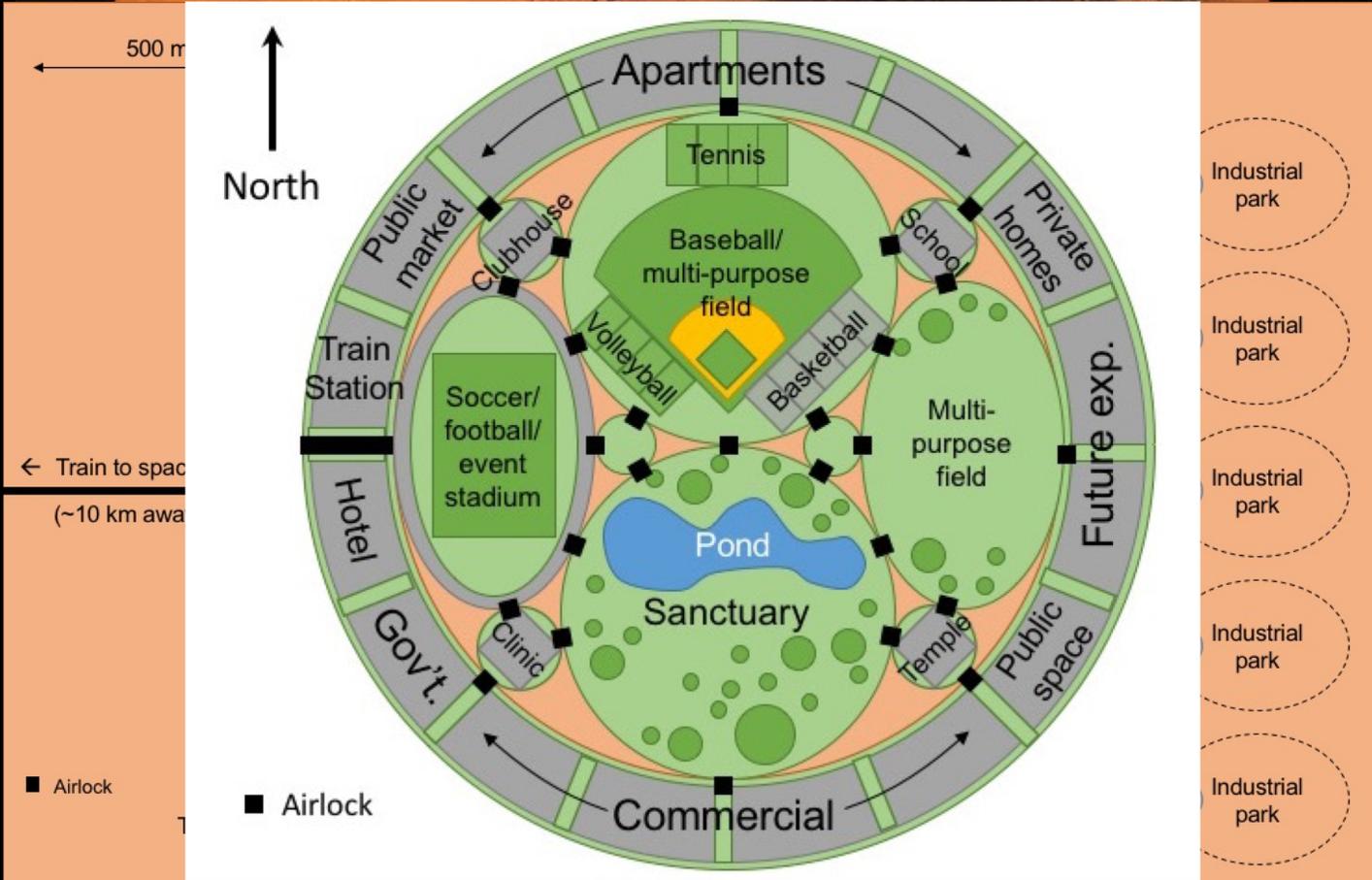
Central town layout

- Medical facilities:
- Community clinic (Central Park)
 - Main hospital (edge of town)
 - Medical shuttle service (Spaceport)



Sanctuary (200 m dia.)

Extended town layout



Agricultural activities

- Produces all food and fiber colony needs
- Roughly 100% surplus exported to elsewhere on Mars, Moon, orbital locations
- A variety of plants grown to provide complete human and animal nutrition
- Fiber plants: flax, hemp, poplar, bamboo for clothing, textiles, paper, luxury wood
- Livestock: mainly fish & insects, with limited chickens, goats, cows, etc. grown for eggs, milk, wool, some luxury meat
- Land mammal/avian air and water cycles isolated from K-Town residents to minimize possible disease outbreaks



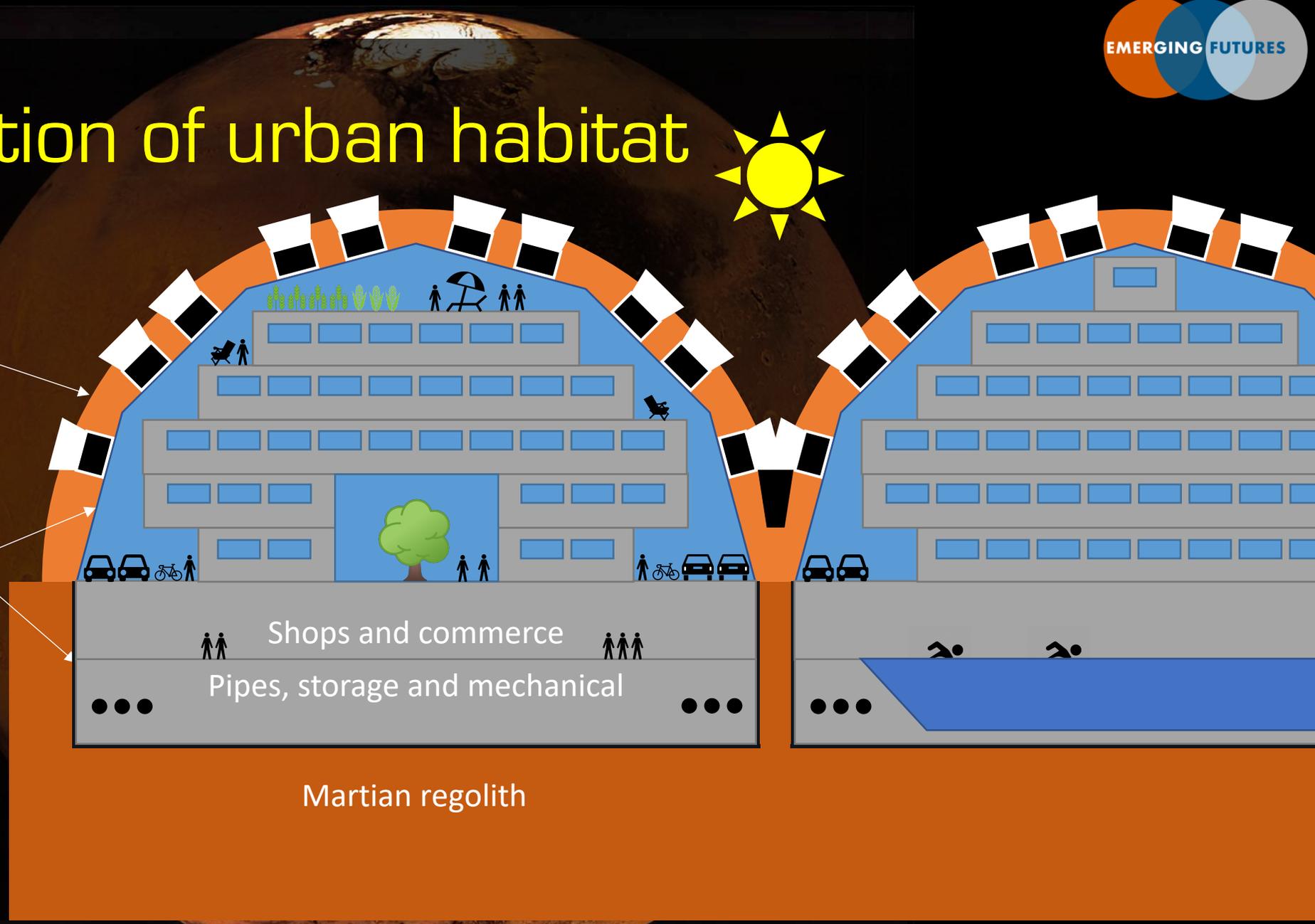
Cross-section of urban habitat

~3 m of regolith for micrometeorite and radiation shielding (plus glass for natural light)

50 m dia. half-cylinders
12 m underground area

6 m² average interior space per m² footprint

Many configurations possible



Martian regolith

Based on design by Eric Ward (Aten Engineering) and Brian Unger (Astraea)

Overall mass and energy flows: ASTER

Use of in-house ASTER model: Analysis of Space Technologies, Economics and Resources

Quantity	Total output	Units	Fraction of total consumed				
			Urban	Agricultural	Propellant	Other industrial	Exported
Water	88	kg/s	8.05%	35.83%	21.68%	34.37%	0.08%
Food (dry basis)	0.068	kg/s	30.57%	35.80%	0.00%	3.36%	30.27%
Fiber (dry basis)	0.0032	kg/s	49.52%	0.00%	0.00%	1.46%	49.02%
CO2	21.5	kg/s	0.00%	0.85%	97.31%	1.84%	0.00%
N2 + Ar	0.96	kg/s	4.05%	0.00%	0.00%	55.83%	40.12%
CH4	7.63	kg/s	0.00%	0.00%	85.23%	8.60%	6.17%
O2	30.5	kg/s	0.03%	0.05%	76.34%	17.73%	5.84%
Steel	0.88	kg/s	7.70%	0.77%	2.36%	78.50%	10.67%
Concrete	3.00	kg/s	22.69%	44.83%	0.08%	32.40%	0.00%
Glass	2.41	kg/s	86.72%	4.33%	0.00%	8.95%	0.00%
Regolith	283	kg/s	0.54%	0.31%	0.00%	99.15%	0.00%
Electricity	1,000	MW	0.12%	6.36%	49.03%	44.48%	0.00%

Economics (Akhil Rao, Ph.D.)

- Depreciating licenses: solve inefficient asset development investment problem
- (Unimproved) Land Value tax: raise revenue while “taxing least elastic decisions”
- K-Town Central Bank: maintain price stability, encourage savings, cap inflation
- Solow model to estimate initial investment:
 - Cobb-Douglas production equation that assumes labor-augmenting technologies
 - Constant total returns to scale in capital and labor
 - Flexible but conservative immigration policy maintains scarce labor market
- Initial investment of \$2.25 B (including transportation costs) in 2030 to attain target economic output in 2049
- Economy now >100x this size, with capital inflows of \$30 B/M-yr.
- Debt is paid and now returns substantial dividends to early investors
- One of the most attractive off-world investments!

Exports of key materials

Carbon and nitrogen resources offer advantages over other locations:

- Methane-based propellant (plus ethylene, propylene, etc. if demand exists)
- Nitrogen (and argon) inert gases
- Food, fiber, organic chemicals

Superior infrastructure can compete with low-g locations (e.g., Moon, asteroids):

- Water and oxygen (both gaseous and liquefied)
- Metals/ceramics and manufactured parts
- Platinum group metals (PGMs)

Resources unique to Mars:

- “Made on Mars” items: rocks, agricultural products, manufactured artifacts, art
- “Mars” gold (maybe)

Overall economic benefit of exports

Item	Destination(s)	Mass flow (t/M-yr.)	Gross revenue (\$M/M-yr.)	Costs (\$M/M-yr.)***	Profit (\$M/M-yr.)
Metals and metal parts	Orbital**	5,586	729.0	656.1	72.9
Water	Orbital**	4,118	537.5	483.7	53.7
Oxygen	Orbital**	5,713	684.6	616.1	68.5
Nitrogen/Argon	Orbital*	22,851	3,488.3	3,139.5	348.8
Food (dry)	Orbital*	1,224	203.5	183.2	20.4
Propellant - LCH4	Orbital*	27,931	4,896	4,407	490
Propellant - LO2	Orbital**	100,086	12,824	11,542	1,282
Plastics	Orbital*	40.0	6.6	6.0	0.7
Organic chemicals	Orbital*	79.9	13.3	12.0	1.3
Fiber	Orbital*	93.1	15.5	13.9	1.5
PGM	Orbital*	9.13	373.0	335.7	37.3
"Mars" gold	Orbital*	5.93	382.3	191.6	190.7
"Made on Mars" products	Orbital*	18.8	17.3	4.5	12.8
Total		167,757	24,171	21,591	2,581

*45% Earth orbits, 35% Mars orbits + Lagrange points, 10% nearby asteroids, 10% Mars surface
 **Only non-Earth orbits: 70% Mars orbits + Lagrange points, 20% nearby asteroids, 10% Mars surface
 ***Includes 90% of launch costs + production costs

Exports comprise <10% of GDP

"Beneficial but not dependent"

Politics and culture

- Representative unicameral democracy (elect 17 reps every M-year)
- Popular vote to elect mayor (reelected every 2 M-years)
- Quadratic voting: gives minorities power, avoids tyranny of majority
- Citizens can vote at 9.5 M-years (about 18 E-years) of age
- Other governmental positions are appointed or competitively hired
- Universal basic income: provides social safety net, encourages risk taking
- Culture of creativity, “attack ideas, not people,” “fail fast,” and, of course, fairness, tolerance and diversity
- Eight M-day “week” with 3 M-day weekend!!
- There is a future for you in K-Town; join us!

Thank you!

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