



SOLVING THE WORLD'S ENERGY PROBLEM FOR GOOD

A NEW ERA OF SPACE ENTERPRISE FOR HUMANITY

Jim Keravala, COO, Shackleton Energy Company
3D Additive Construction for Space using In-Situ Resources
Keck Institute for Space Studies
25th August, 2015



EARTH'S POWER CONSUMPTION WILL INCREASE SUBSTANTIALLY THIS CENTURY

2015

WORLD POWER CONSUMPTION

17 TERAWATTS

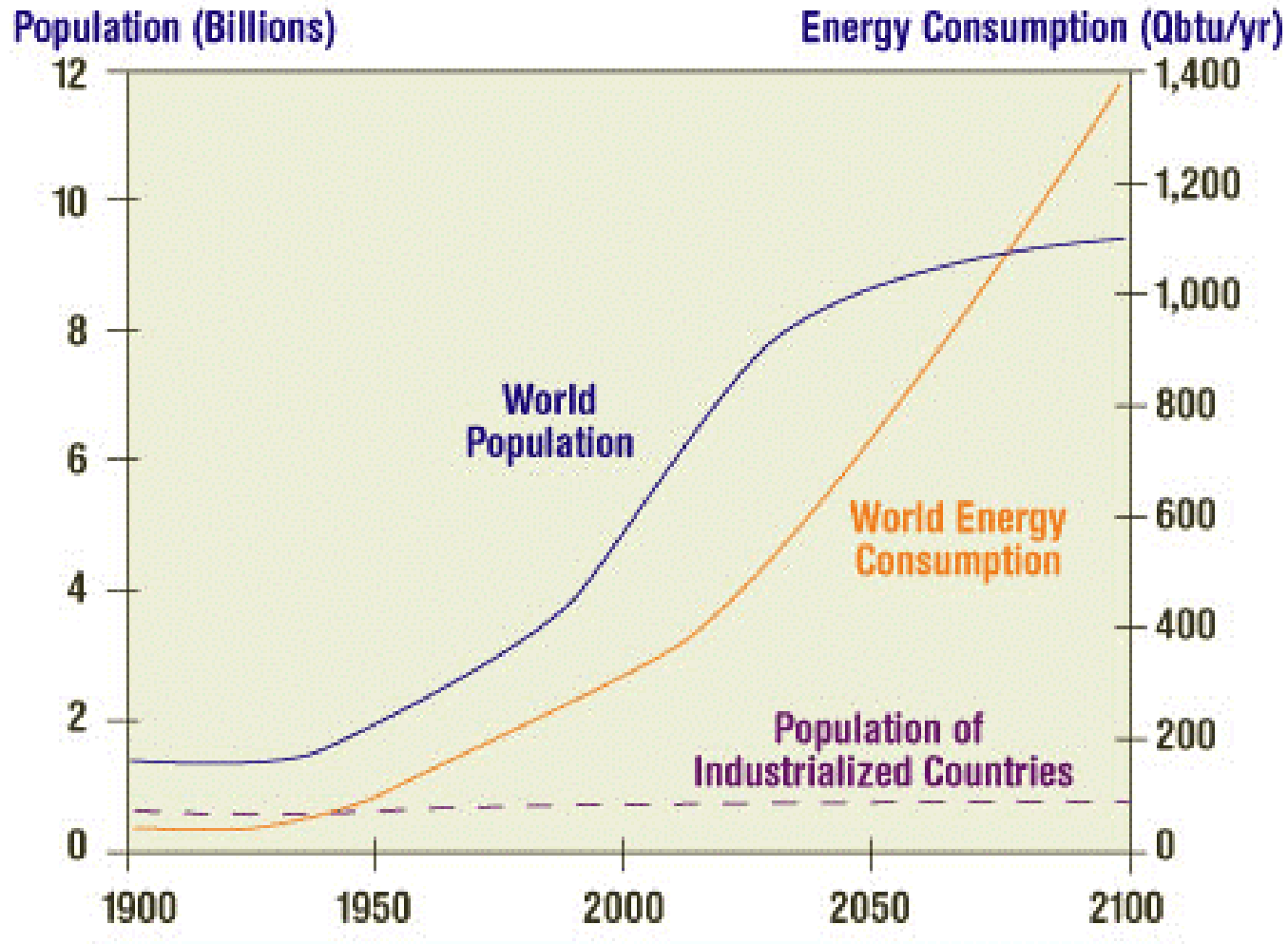


2100

WORLD POWER CONSUMPTION

100 TERAWATTS

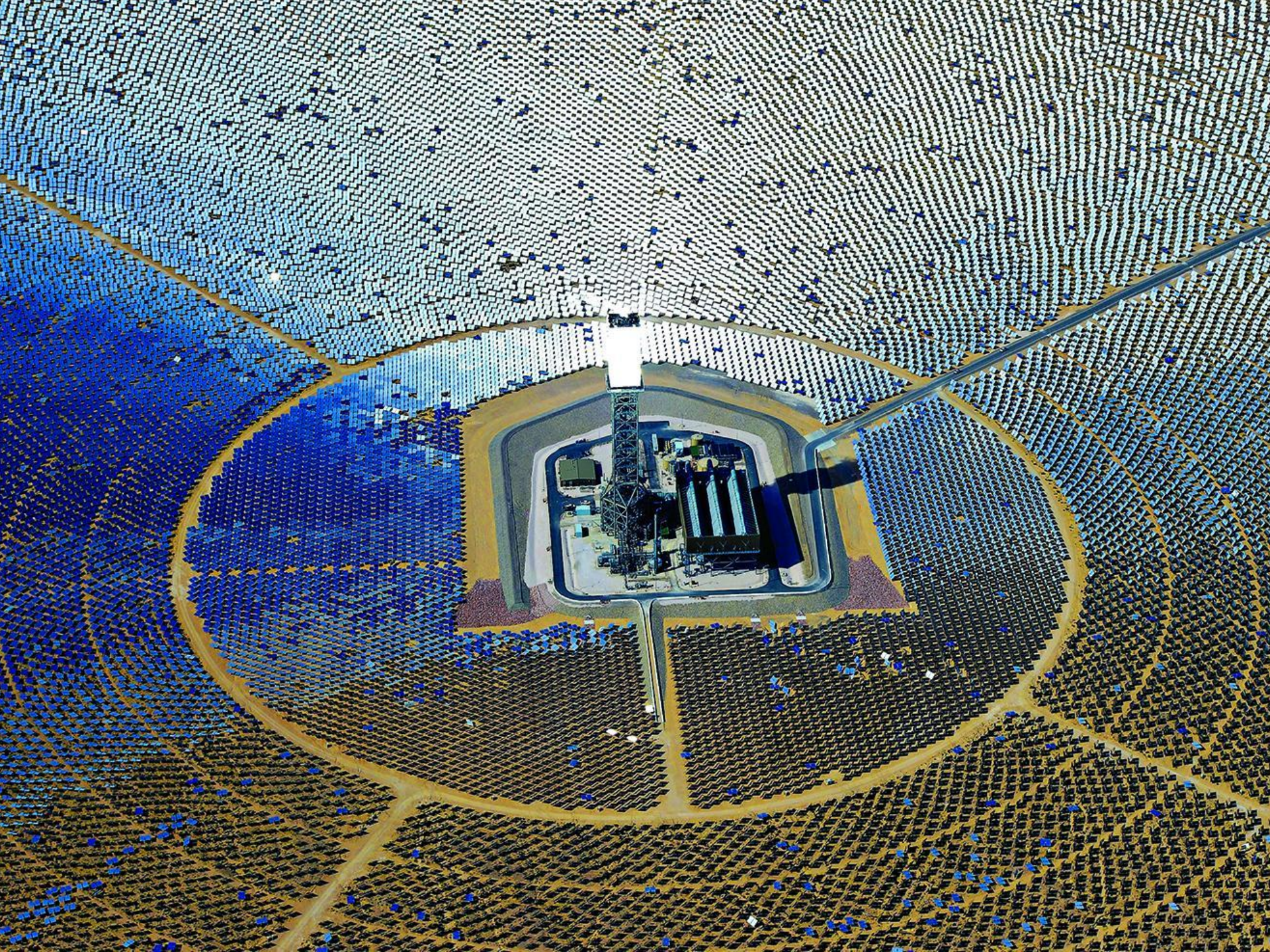
EARTH'S POWER CONSUMPTION WILL INCREASE SUBSTANTIALLY THIS CENTURY



Population Projections: United Nations "Long-Range World Population Projections: Based on the 1998 Revision"
Energy Projections: "Global Energy Perspectives" ITASA / WEC

G7 COUNTRIES AGREE TO PHASE OUT FOSSIL FUELS BY 2100

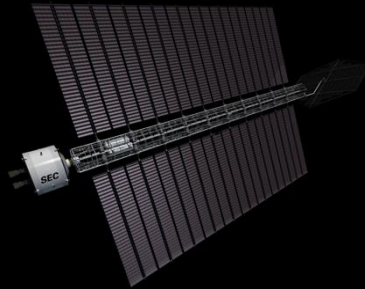




EXCEPT NOW IMAGINE THESE SOLAR FARMS IN SPACE.

CAPTURING SOLAR ENERGY IN SPACE IS 10-40 TIMES MORE EFFICIENT.

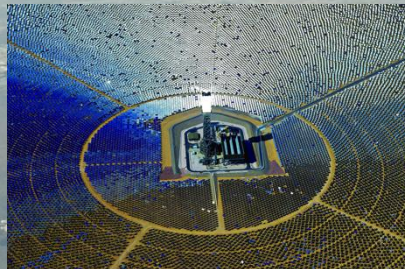
GEOSTATIONARY ORBIT
36,000 km



1,440


WATTS PER M²

- DAY-NIGHT CYCLE
- ATMOSPHERIC LOSSES
- SUNLIGHT ANGLE



36-144

WATTS PER M²



**WE'LL NEED 10-40X LESS
INFRASTRUCTURE**



- #1: ELECTRICITY FOR 10 BILLION PEOPLE**
- #2: EXCESS POWER FOR WATER DESALINATION**
- #3: 100X INFORMATION BANDWIDTH**

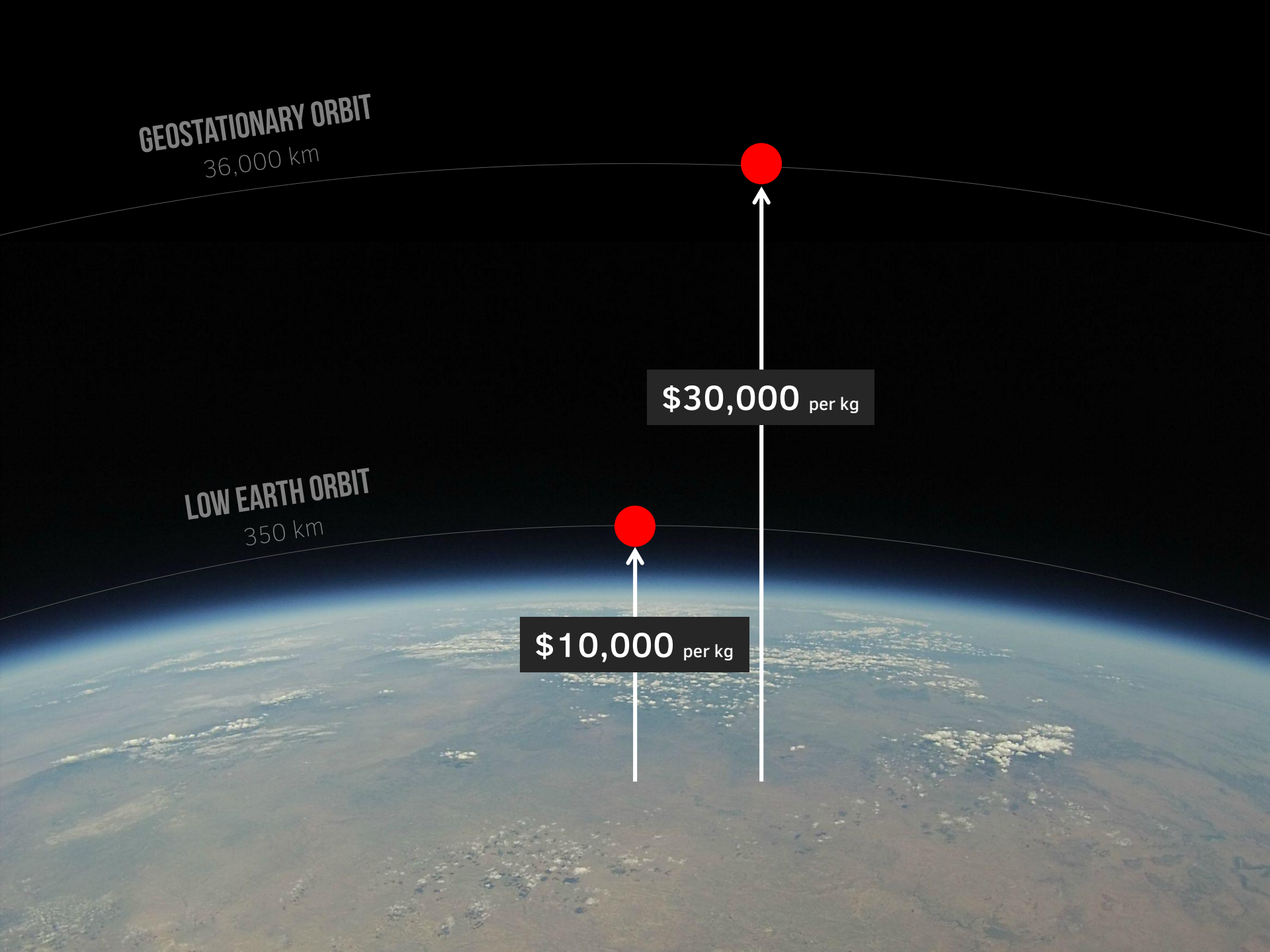
**“GREAT. EXCEPT...
IT WILL NEVER HAPPEN.”**

GEOSTATIONARY ORBIT
36,000 km

LOW EARTH ORBIT
350 km

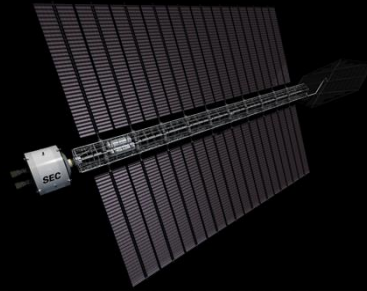
\$30,000 per kg

\$10,000 per kg



TRANSPORTING INFRASTRUCTURE UP FROM EARTH IS PROHIBITIVELY EXPENSIVE.

GEOSTATIONARY ORBIT
36,000 km



SOLAR FARMS IN GEO
BUILT ON & LAUNCHED FROM EARTH

\$30
TRILLION CAPEX

\$30,000 per kg



**“WELL, MAYBE ONE DAY,
WHEN LAUNCH COSTS DROP BY 95%...”**

OR...

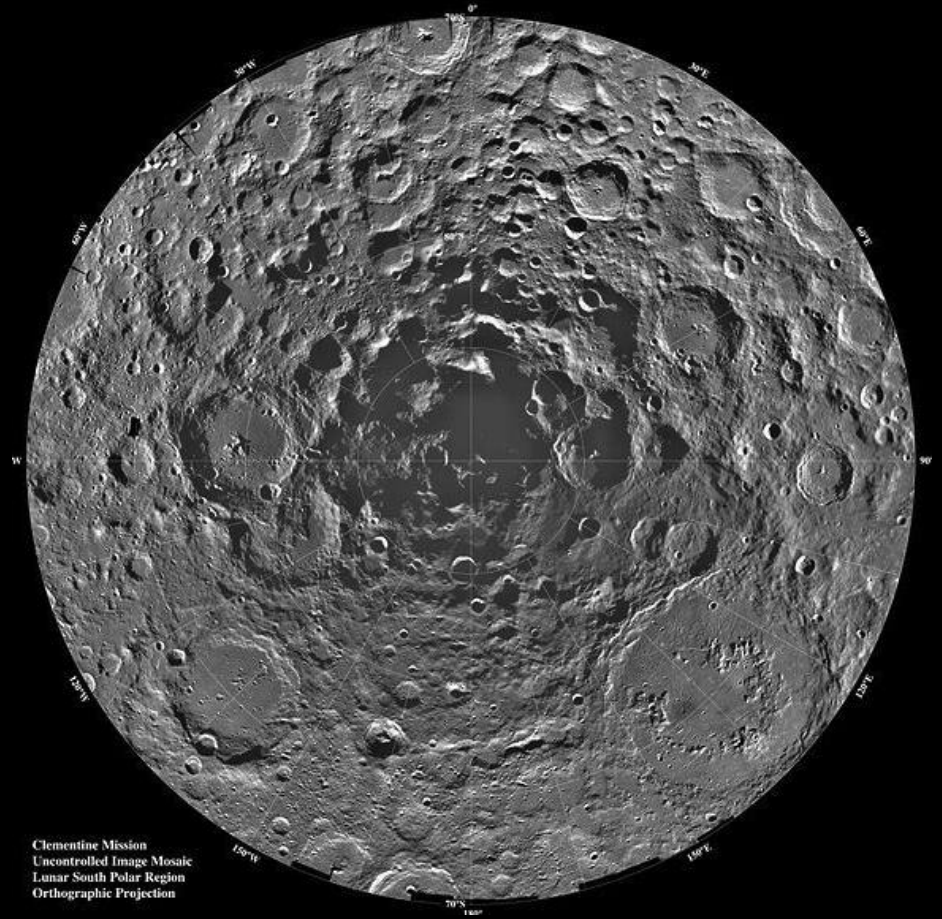
**WE THINK BIGGER,
IN SYSTEMS AND
DOWN, NOT UP.**

WE HAVE THE RIGHT RESOURCES ON THE MOON.

**1.6 BILLION TONS OF WATER ICE
FOR FUEL**

+

**99% OF MASS MATERIALS FOR
SOLAR POWER SATELLITES**



Clementine Mission
Uncontrolled Image Mosaic
Lunar South Polar Region
Orthographic Projection

USING LUNAR RESOURCES TO BUILD SOLAR POWER STATIONS MAKES THE IDEA ECONOMICALLY VIABLE.



\$30,000 per kg

SOLAR STATIONS
BUILT ON & LAUNCHED FROM EARTH

\$30
TRILLION CAPEX

GEOSTATIONARY ORBIT
36,00 km

\$250 per kg

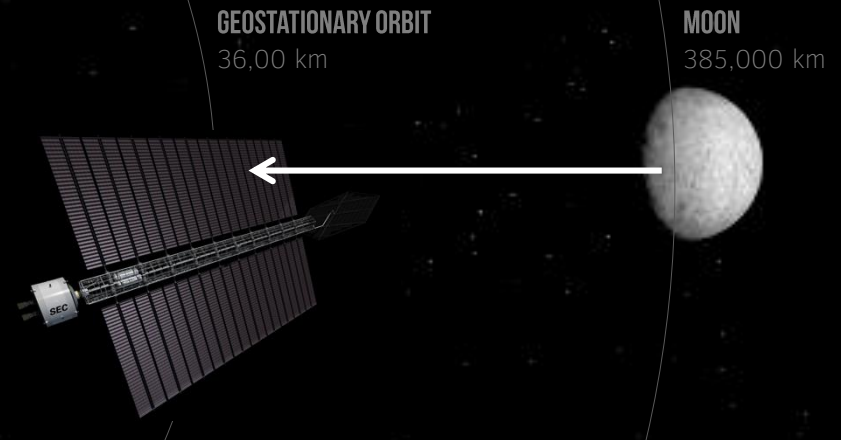
SOLAR STATIONS
BUILT ON & LAUNCHED FROM THE MOON

\$0.17
TRILLION CAPEX

MOON
385,000 km



WE CAN SOLVE WORLD'S ENERGY, WATER AND INTERNET CHALLENGES IN ONE GO.



Solar stations, doubling as communications platforms in geostationary orbit (36,000 km above Earth's surface) are the cleanest, most efficient and most elegant way to supply 30 terawatts of power to 10 billion people by 2100. Excess power can be used to desalinate water. Gigabit internet trunk communications can be modulated on to the transmission beam. The addressable market for this combined infrastructure by 2050 will be almost \$3 trillion for wholesale electricity alone.

ECONOMIC VALUE OF THE MOON:
\$250 PER KG TRANSPORTATION COST TO GEO

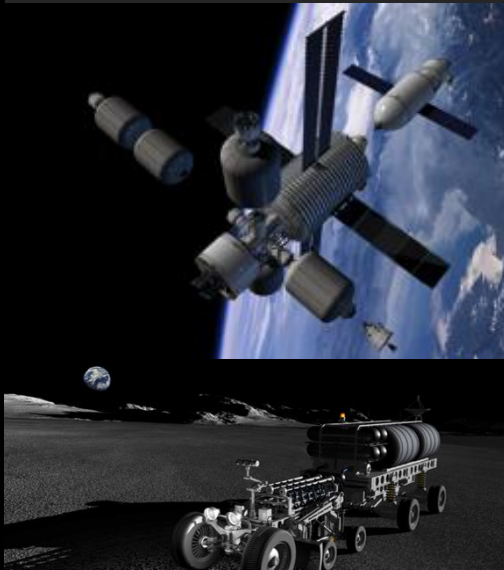
WE WILL PROCEED IN THREE PROGRAMS.

2015-2023

PROGRAM 1

**Fuel Station & Lunar
Supply Chain**

Estimated cost \$18 billion



2024-2030

PROGRAM 2

**Manufacturing
on the Moon**

Estimated cost \$40 billion



2031-2100

PROGRAM 3

**Off-World Solar Power &
Internet**

Estimated cost \$270 billion



EACH PROGRAM WILL CREATE NEW MARKETS.

2015-2023

PROGRAM 1

Fuel Station & Lunar
Supply Chain

Estimated cost \$18 billion

2024-2030

PROGRAM 2

Manufacturing
on the Moon

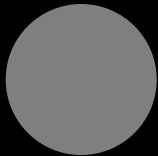
Estimated cost \$40 billion

2031-2100

PROGRAM 3

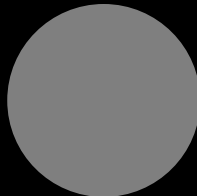
Off-World Solar Power &
Internet

Estimated cost \$270 billion



\$80 BILLION IN 2030

OFF-WORLD TRANSPORT VEHICLES
ORBITAL SERVICES
FUEL

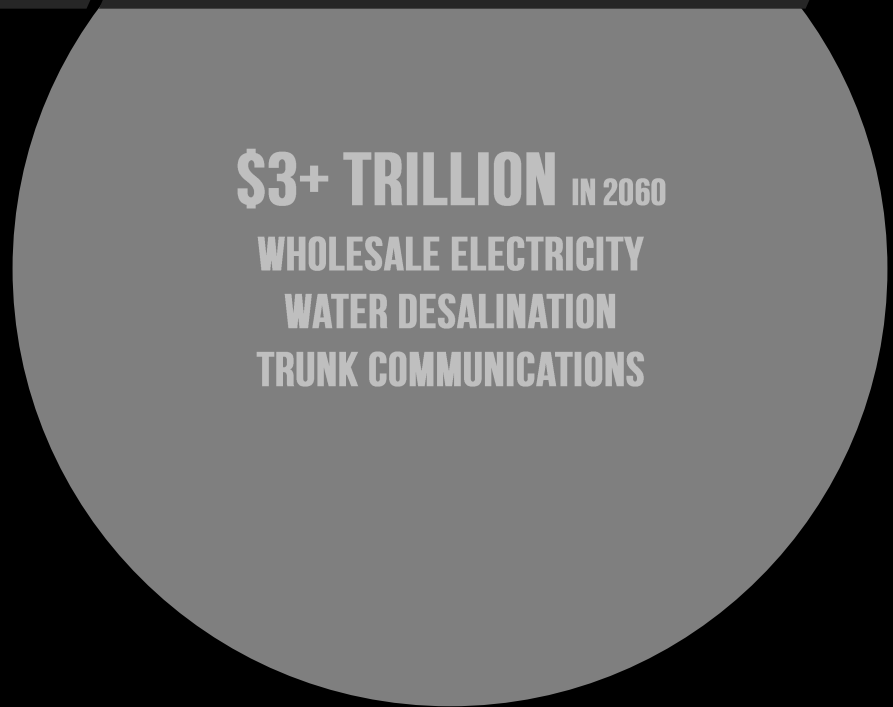


\$100 BILLION IN 2050

LUNAR EXTRACTION &
MANUFACTURING

\$3+ TRILLION IN 2060

WHOLESALE ELECTRICITY
WATER DESALINATION
TRUNK COMMUNICATIONS



**WE'LL USE LUNAR RESOURCES
FOR THE COMMON BENEFIT OF ALL HUMANKIND.**

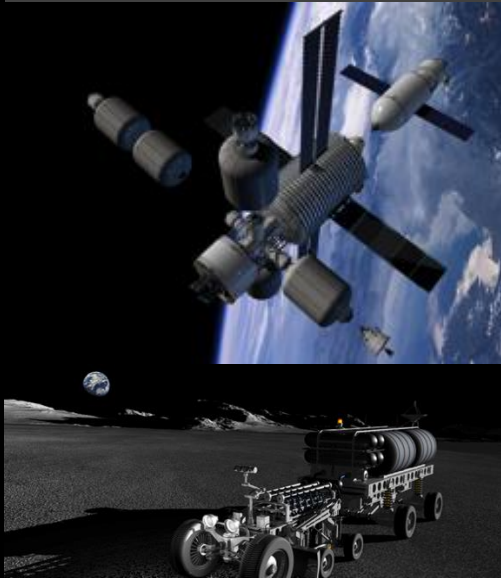
WE WILL USE THE INCOME STREAM OF PROGRAM 1 TO FUND THE REST.

2015-2023

PROGRAM 1

Fuel Station & Lunar Supply Chain

Estimated cost \$18 billion



2024-2030

PROGRAM 2

Manufacturing on the Moon

Estimated cost \$40 billion

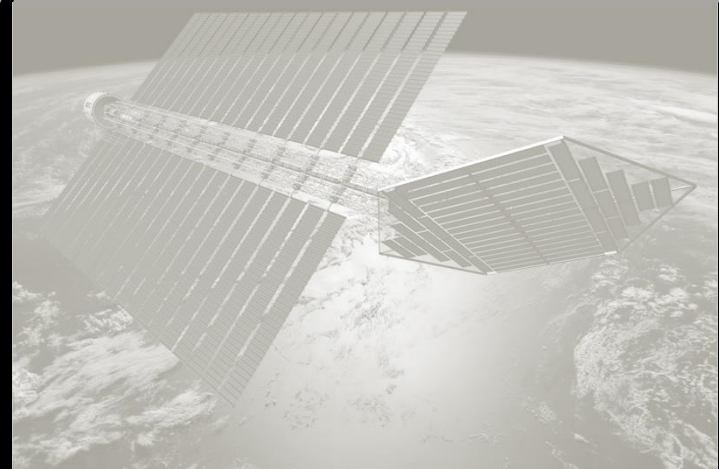


2031-2100

PROGRAM 3

Off-World Solar Power & Internet

Estimated cost \$270 billion



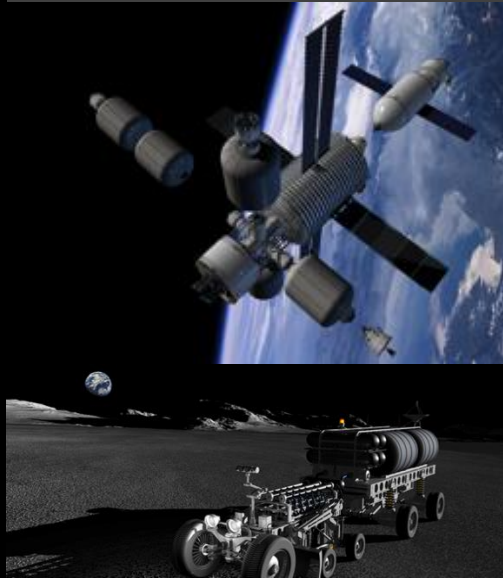
IT HAS BEEN LONG TIME IN THE MAKING.

2015-2023

PROGRAM 1

Fuel Station & Lunar Supply Chain

Estimated cost \$18 billion



20 YEARS IN THE MAKING

The SEC team have been working on the concept of Program 1 beginning in 1995 when the Clementine mission reported detection of water ice on the South Pole of the Moon. Water ice in the deep, cold trap craters represented an opportunity to generate large quantities of rocket propellant by splitting water into hydrogen and oxygen and use it to re-fuel spacecraft in the space between the Moon and low Earth orbit (LEO).

4,000 MAN-YEARS OF EXPERIENCE

Since 2007, Program 1 has been carefully planned—technically and commercially—drawing on contributions from hundreds of experts with the combined aerospace and mining experience of ~4,000 man-years.

THE GOAL IS TO CREATE FUEL STATIONS WITH A LUNAR SUPPLY CHAIN.

FUEL STATION



EXTRACT WATER TO MAKE FUEL



LOW EARTH ORBIT
350 km

GEOSTATIONARY ORBIT
36,000 km

MOON
385,000 km



PROGRAM 1 WILL CREATE TWO REVENUE-GENERATING ASSETS.

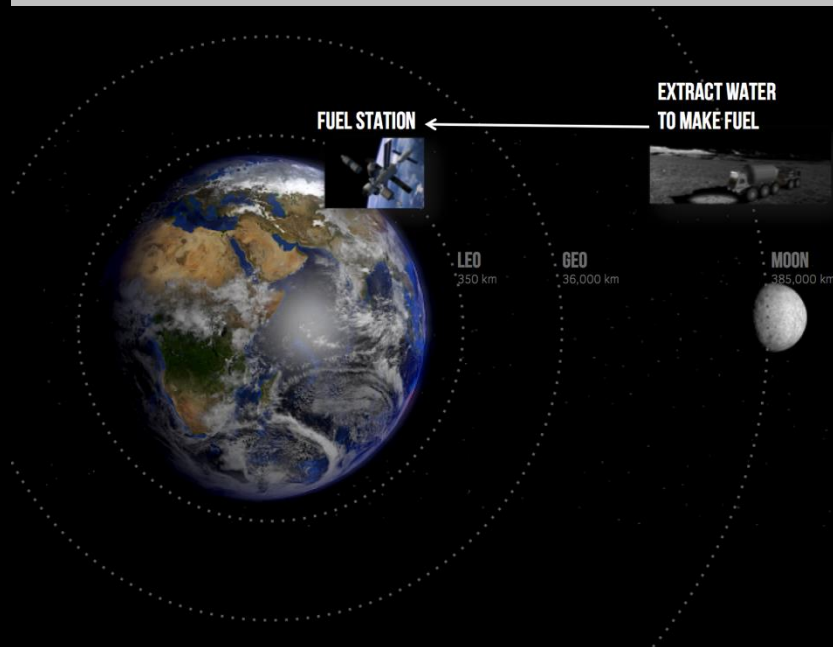
Asset #1:

Fuel station in LEO with a lunar supply chain of fuel

1,040

**METRIC TONNES
OF FUEL**

Total annual production capacity of SEC's lunar supply chain, consisting of 71 spacecraft and lunar modules.



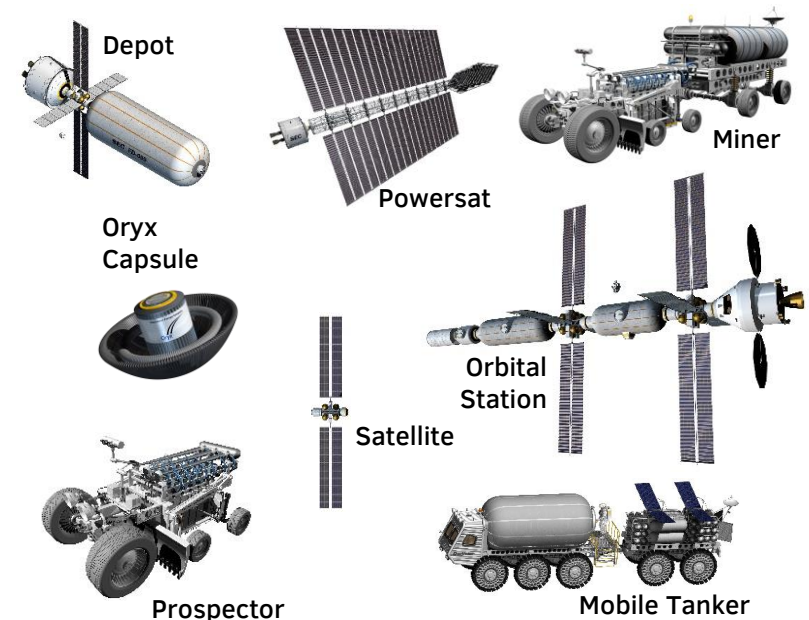
Asset #2:

Production line for a new generation of reusable spacecraft

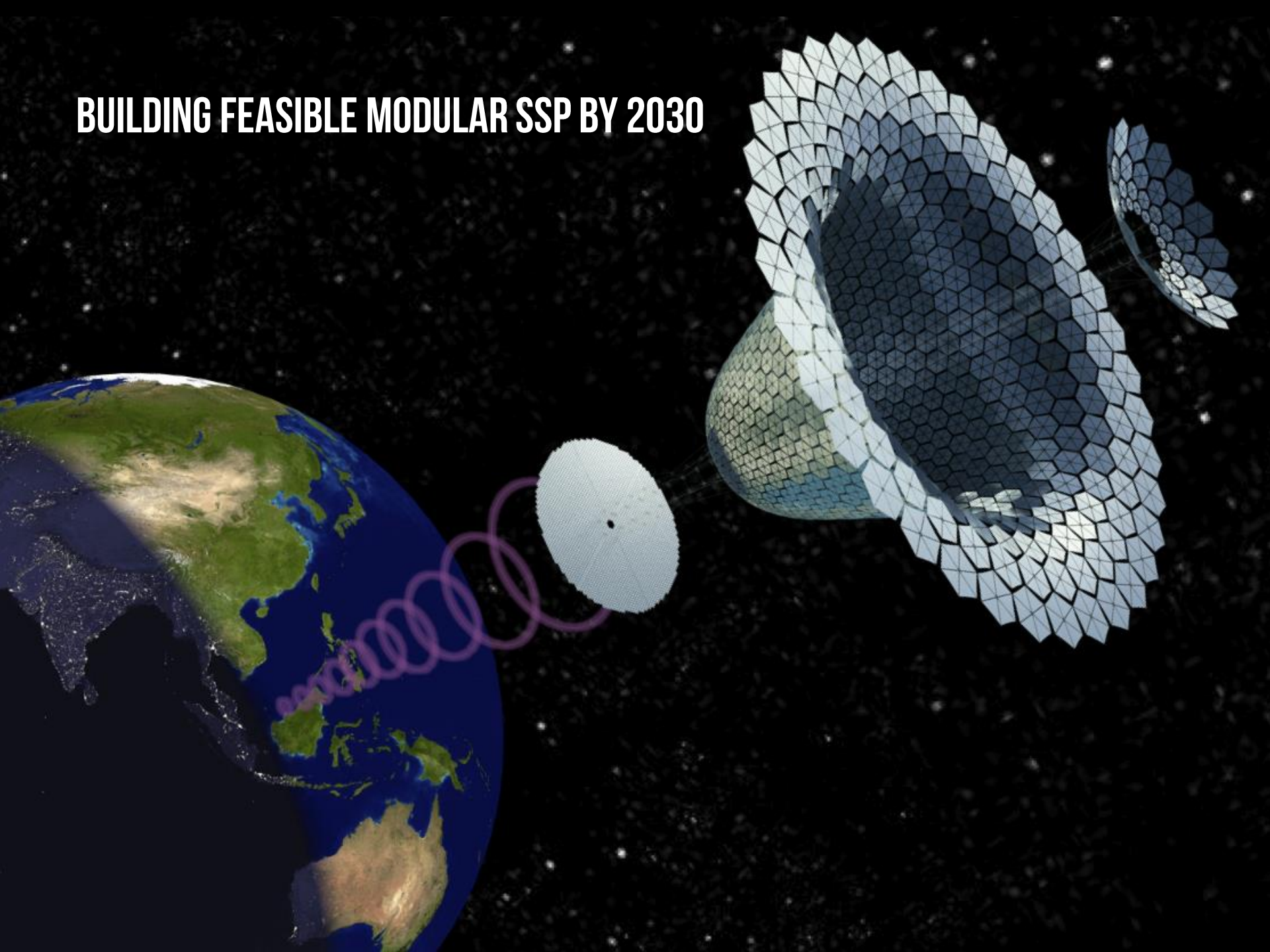
30

SPACECRAFT

Total annual production capacity of facilities used to produce SEC's new generation of modular, reusable and refuelable spacecraft and modules.



BUILDING FEASIBLE MODULAR SSP BY 2030



THREE GUIDING OPERATING SYSTEMS

OFF-WORLD COUNCIL

Needs of
Humankind

OFF-WORLD FUND

Equality of
Investors

OFF-WORLD DEVELOPERS

Efficiency of
Operations

GOVERNANCE FRAMEWORK FOR OFF-WORLD CONSORTIUM

Primary governance role:
Foresight

OW COUNCIL

Multi-lateral
membership
organization

Mandate: Secure
“common benefit for
all humankind”

OW FUND

Investment fund with
sovereign and
private investors

Mandate: Finance
OW Operations

Primary governance role:
**Control & Compliance
Accountability**

MASTER DEVELOPER

Mandate: Deliver
Operations in the
most efficient and
effective way

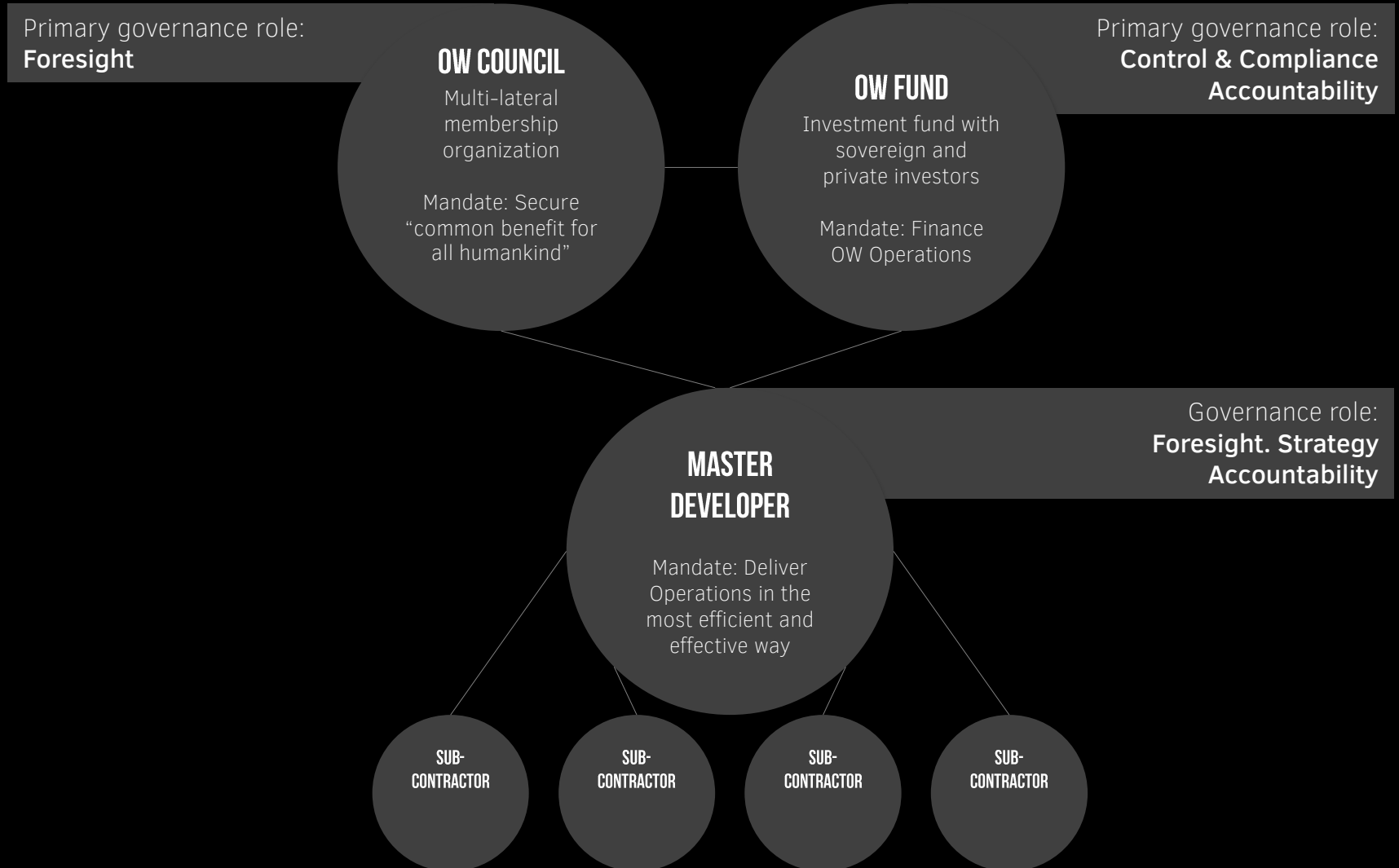
Governance role:
**Foresight. Strategy
Accountability**

SUB-
CONTRACTOR

SUB-
CONTRACTOR

SUB-
CONTRACTOR

SUB-
CONTRACTOR



**USING LUNAR RESOURCES
TO SCALE SPACE BASED SOLAR POWER THIS CENTURY**

**OFF-WORLD CONSORTIUM
LAUNCHING 2016**

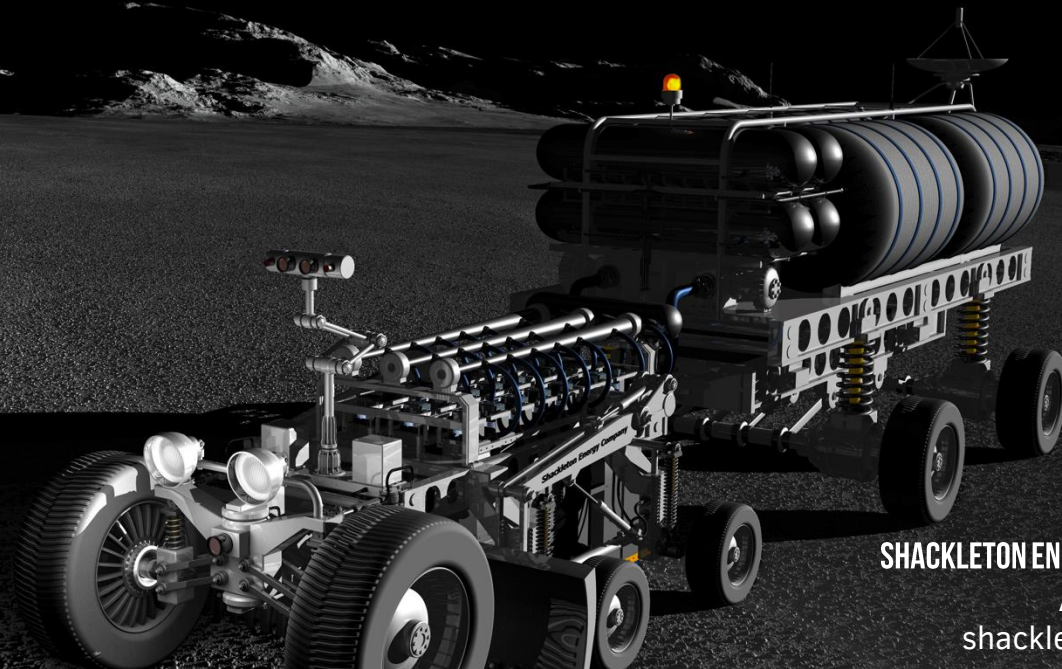


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