XArc
Exploration Architecture Corporation

Developing a Global Spaceport Network for Point-to-Point Cargo Logistics

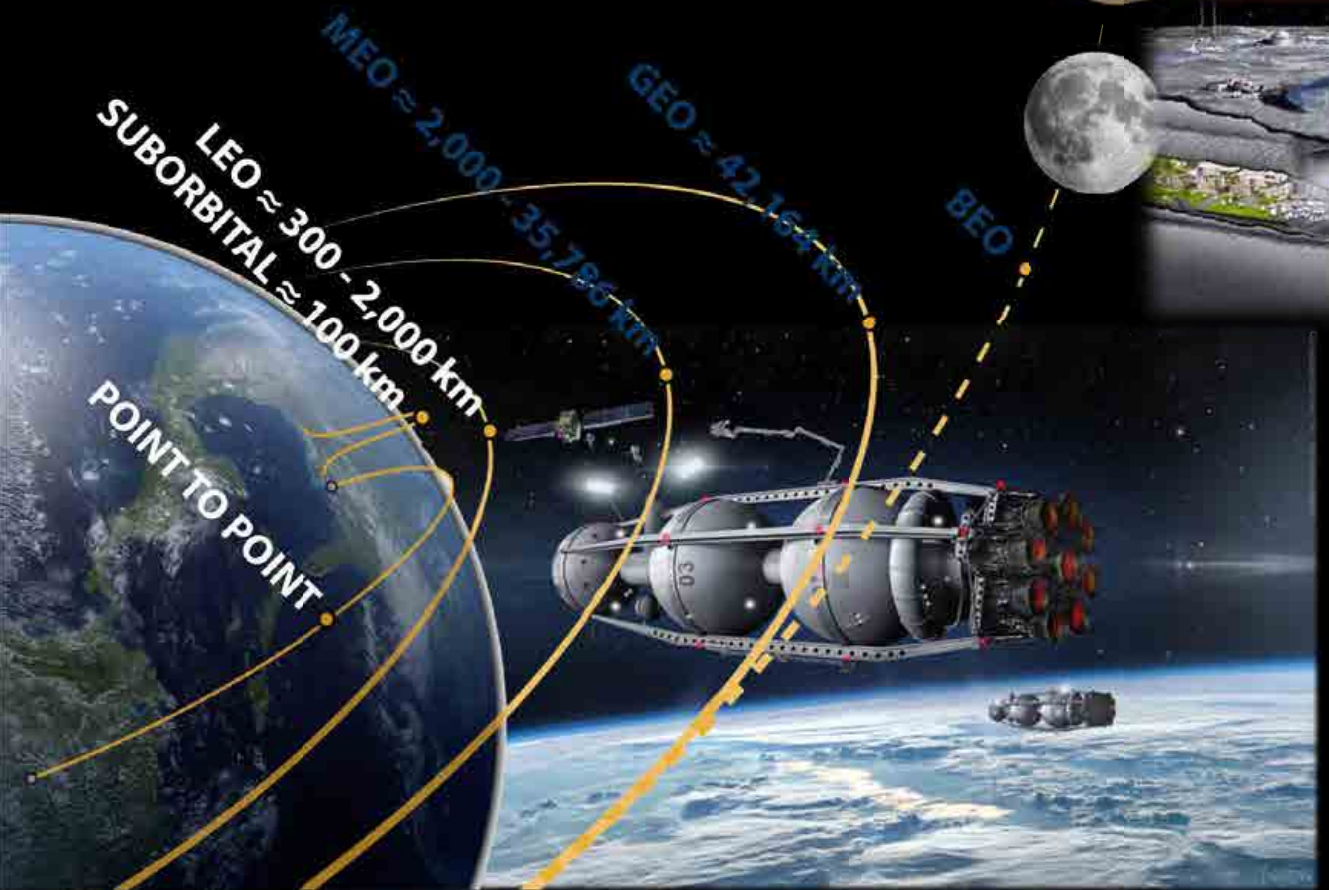
2023 USTRANSCOM International Logistics Symposium

DCCC
Scott Air Force Base, Illinois

15 June 2023

Sam Ximenes, Space Architect
XArc

Space Logistics
Supply Chain of the Future



Why this is relevant

Space flight will be accessible to a larger portion of the population.

There is a future arriving where

A Commercial Space Transportation Network of global spaceports is currently in development.

Global spaceports will be used for high-speed, point-to-point transportation.

Outline

- Introduction
- Company Background
- Space Vehicle Transports
- Orbital Depots
- Spaceports
- P2P Use Cases
- Ground Support & Logistics
- Basing Considerations
- Regulatory Considerations
- XArc Spaceport Development Process
- Q&A

Space Architecture

Established in 2007

Practice in three principal domains of Space Architecture

Terrestrial Space Facilities Architecture

Spaceports

Orbital Architecture

Space Stations

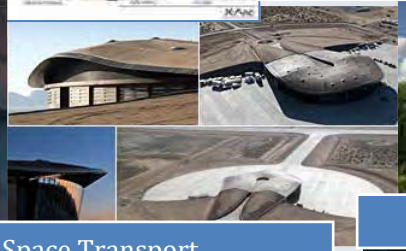
Planetary Surface Systems Architecture

Infrastucture

CONCEPT DEVELOPMENT & DECISION SUPPORT SERVICES FOR INTERPLANETARY ARCHITECTURE PROJECTS

Terrestrial Space Architecture Projects

Spaceport America Terminal & Hangar Facility Programming/ Site Assessment/ Fueling Ops



Multimodal Transportation Hub

Air Traffic Control Tower

Houston Spaceport
Economic & Business Study plus Concept Development


HOUSTON SPACEPORT ENTRANCE

PROMOTIONAL VIDEO


SPACEPORT TERMINAL (AIRSIDE)


SPACEPORT AEROSPACE MUSEUM


SPACEPORT TERMINAL (LANDSIDE)


SPACEPORT TAXIWAY


SPACEPORT AERIAL NIGHT VIEW

USTRANSCOM Global Space Transport
Space Transportation Basing and Support Concepts

Rocket Cargo System

UK Spaceport
Multi-Site Criteria Assessments

Space Transports

Spacecraft Type

Mothership Horizontal Takeoff/Horizontal Landing			Single Stage Horizontal Takeoff/Horizontal Landing					Heavy Lift Vertical Launch and Return	
Stratolaunch	Virgin Galactic SpaceShip2	SNC Dream Chaser	Blue Origin New Shepard	Northrop Grumman Pegasus XL	Radian Aerospace Radian 1	Skylon Reaction Engines	Virtus Solis Prometheus	Blue Origin New Glenn	SpaceX Starship
									
Relative Payload Capacity to Low Earth Orbit									
13,500 lbs.	1,300 lbs. 8 crew	11,000 lbs.*	900 lbs. 6 crew	977 lbs.	5,000 lbs.	37,000 lbs.	38,000 lbs.	99,000 lbs.	220,000 lbs.
Potential for Special Airlift Assignment Mission (SAAM), i.e., VC-25, C-32, C-40, C-37, and C-20 aircraft assignment type missions (*11,000 lbs. uplift / 3,860 lbs. downlift)			Limited range, not PTP viable	Not viable for PTP cargo transport	Potential for human transport		C130J  42,000 lbs.		C-17  179,000 lbs.

Orbital Depots

In-Space Manufacturing (ISM)

Factories in Space

1: Launch / Re-supply

Equipment launched from Earth.
Raw materials & consumables from:
1) Earth
2) recycling
3) Moon
4) asteroids

Space Resources Transport
Momentus, TransAstra, Orbit Fab

Space Debris Recycling
Made in Space, CisLunar Industries, Orbit Recycling, Tethers Unlimited

Re-Supply Vechicles (1-way)
Cygnus, Progress, HTV, Tianzhou

Re-Supply Vechicles (2-way)
Dragon, Starship, Starliner, Dream Chaser, Sojuz

2: On-Orbit Manufacturing

Using microgravity environment to manufacture new products and materials, on or nearby:
1) space stations (multi-use or dedicated)
2) free-flying spacecraft (multi-use or dedicated)

Space Stations
ISS, Gateway, Tiangong

Microgravity End-to-End Services
Nanoracks, Ice Cubes, Bartolomeo, Space Tango, yuri

Commercial Space Stations
Axiom, Nanoracks, Orion Span, Orbital Assembly

Dedicated Space Factories

In-Space Construction/Assembly
Made in Space, Tethers Unlimited, Orbital Assembly, Arkisys, Momentus

Dedicated Free-Flyers
Dragon, Space Tango, Space Forge, Space Rider, Dream Chaser, Arkisys

3: Use in Orbit / Re-Entry

1) Large-scale space structures, solar power stations, space food etc will remain for use in space. The more accurate term for this activity can be in-space construction or in-space assembly.
2) Re-entry capsule (can be same) to bring samples and products to Earth, which will likely be the largest market for many materials.

Large-Scale Space Structures
Made in Space, Tethers Unlimited, Orbital Assembly, Momentus, Skycorp, United Space Structures

Space Food
Nanoracks

Re-Entry Capsules (1-way)
SpaceWorks, JAXA

Space Vechicles (2-way)
Dragon, Starliner, Dream Chaser, Space Tango, Space Rider, Sojuz

Mission Control

Landing Sites (land)

Spaceports

In-Space Internet

Landing Sites (sea)

Supporting Services

Spaceships (2-way)
Starship

Path 1: Space Station Services

1) Launch orbital factory to the ISS or commercial space station. As preparation or everything at the same time.
1a) Re-supply raw materials & consumables (optional).
2) Use the mostly automated orbital factory and help of (commercial) astronauts to manufacture the material or product in microgravity.
3) Use (the same) space capsule to return the products.

Path 2: Dedicated Free-Flyers

1) Launch reusable spacecraft or space capsule (e.g. Cargo Dragon) with raw materials, consumables and fully automated manufacturing apparatus included.
2) Use the free-flying spacecraft as a microgravity environment for in-space manufacturing.
3) Enter atmosphere & retrieve the (reusable) capsule.

*Lists of examples are not exhaustive

Space Station > Free-Flyer

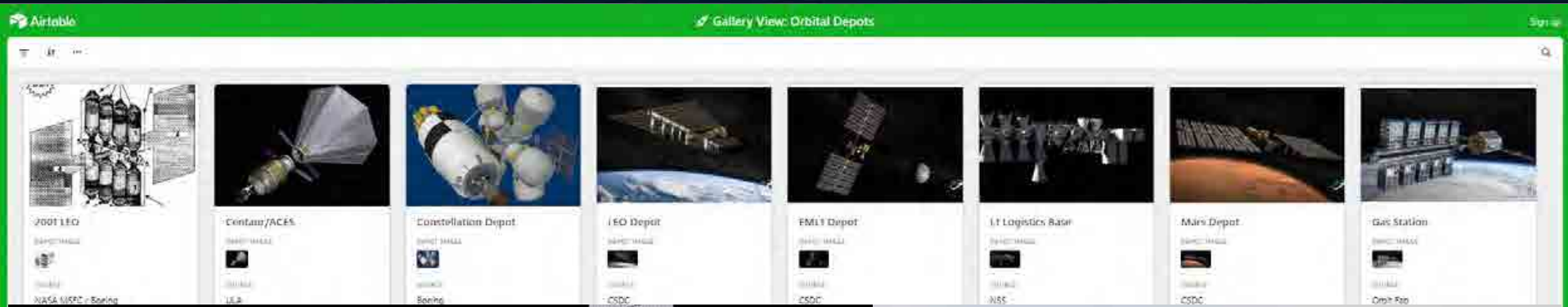
- Regular Dragon, Starliner, Starship etc flights.
- Most not that time-sensitive if extra 1-2 months.
- Quantinities will likely be small for the near future.
- Multi-use and more consumables due to resupply.
- More electrical power thanks to larger solar arrays.
- Fast 24/7 telecommunications and mission control.
- Capsule retrival (tracking, legal, transport) handled.
- Lower costs all around to help with ISM economics.

Free-Flyer > Space Station

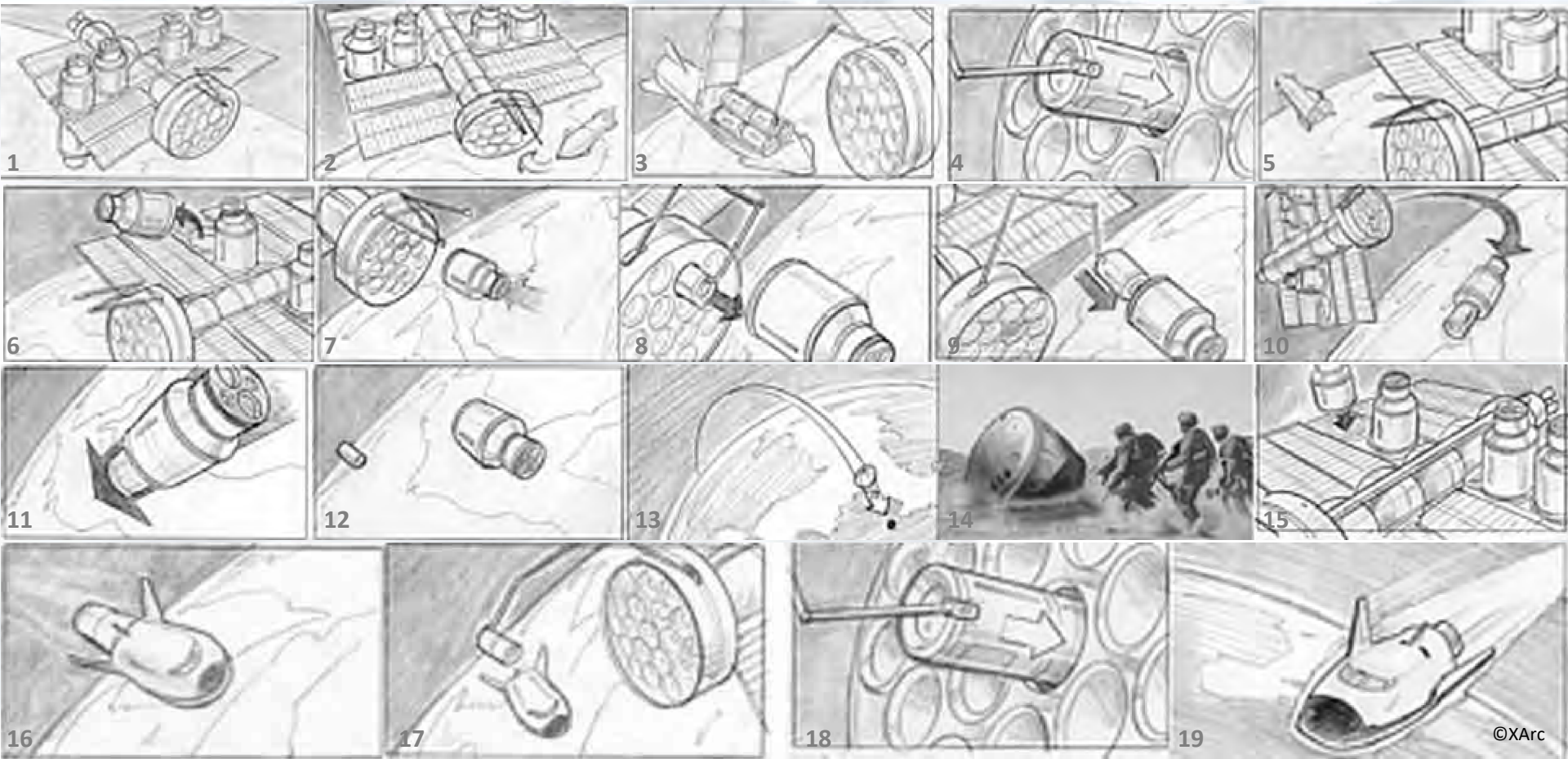
- Re-usable satellites or solo capsules are flexible.
- Independence if aiming for full vertical integration.
- Full use of payload capacity and 100% automation.

factoriesinspace.com
Erik Kulu, 2021-04-04

Orbital Depot Concepts

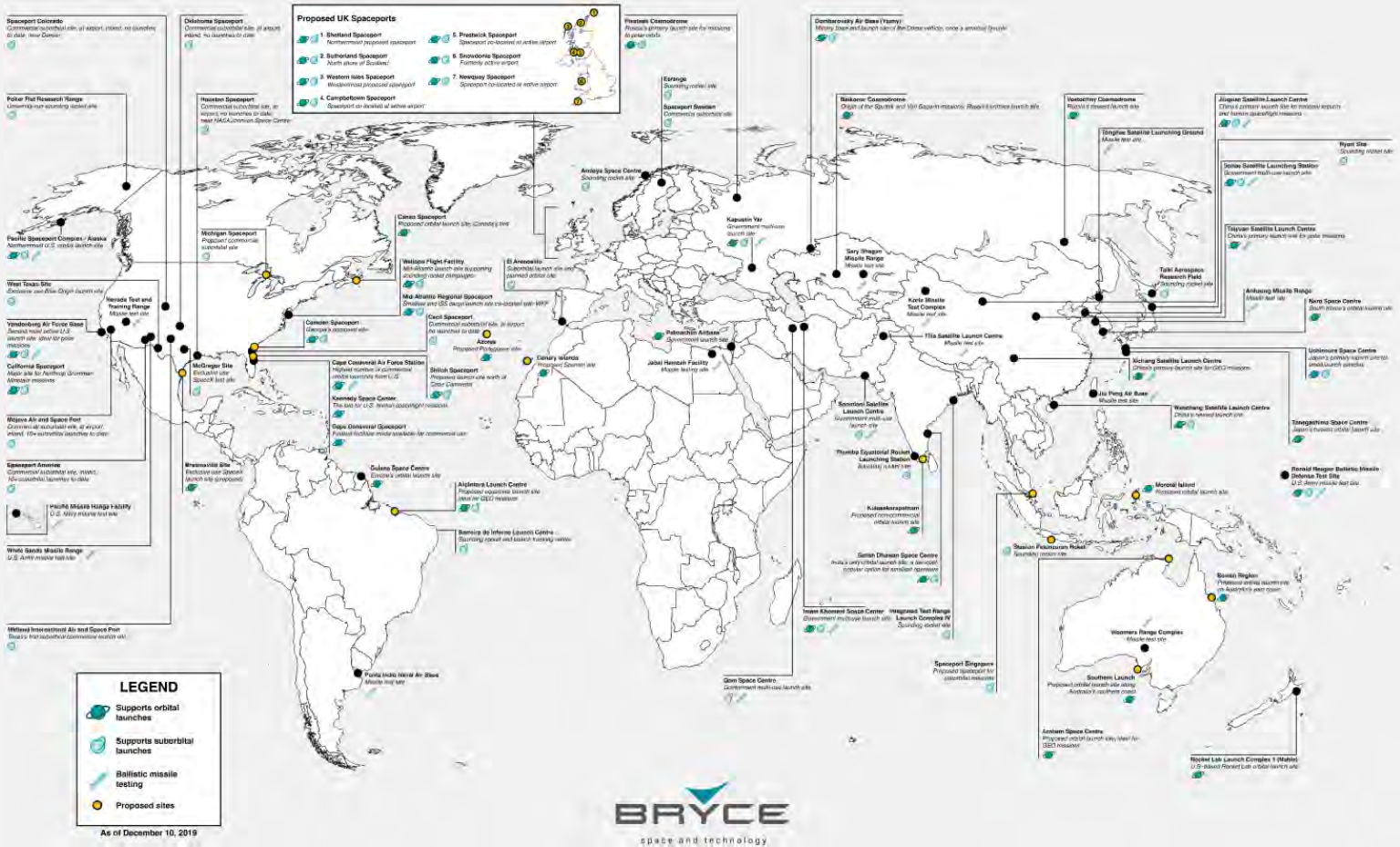


Notional Space Drop Scenario



Spaceports

Global Orbital & Suborbital Launch Sites



BRYCE
space and technology

U.S. Spaceports

Concept for Spaceport Basing Facility

An optimal spaceport basing facility concept with multimodal transport operations servicing space vehicles for both horizontal and verical launch and landing.

Source: Corigan Architects

Concept for Commercial AeroSpaceport

Airport to Spaceport conversion using multimodal air and space transport, servicing commercial airline operations, sub-orbital horizontal takeoff and landing spacecraft, and an eVTOL taxi droneport

Source: XArc

Operational Horizons

Designated four broad spectrum opportunities for suborbital transport utilization:

I. **Direct Action** - Utilization of the PTP vehicle as a means of transportation to an opportune site in order to engage in either political or militaristic actions.

Example: Mobilization of the Global Response Force (GRF) to engage in military actions deemed necessary in order to ensure the safety of civilians and the continuity of both national and allied interests.

II. Humanitarian - Utilization of the PTP vehicle as a means of transportation to an affected region to provide humanitarian or disaster emergency relief to local populations.

Example: A pre-emptive mission that provides critical equipment to mitigate the effects of an impending surge of refugees at a key border crossing, provisioning newly established aid workers with surplus critical equipment.

III. Commercial - Utilization of the PTP vehicle for business-related activities to diminish the lead time as required increasing the firm's profitability and value to shareholders.

Example: An assembly line has encountered a failure of a critical part, causing the line to cease production until the part is replaced or repaired. The overall cost to ship the part utilizing the PTP option is significantly less than the opportunity cost incurred by waiting to repair/replace the part via conventional means.

IV. Black Swan - Utilization of the PTP vehicle to engage in unforeseen and especially unprecedented events..

Example: These situations can only be determined when previously unconsidered external factors become realized, and immediate action needs to be taken to assuage the outcome.

Rocket Cargo

Source: AFRL

Ground Support

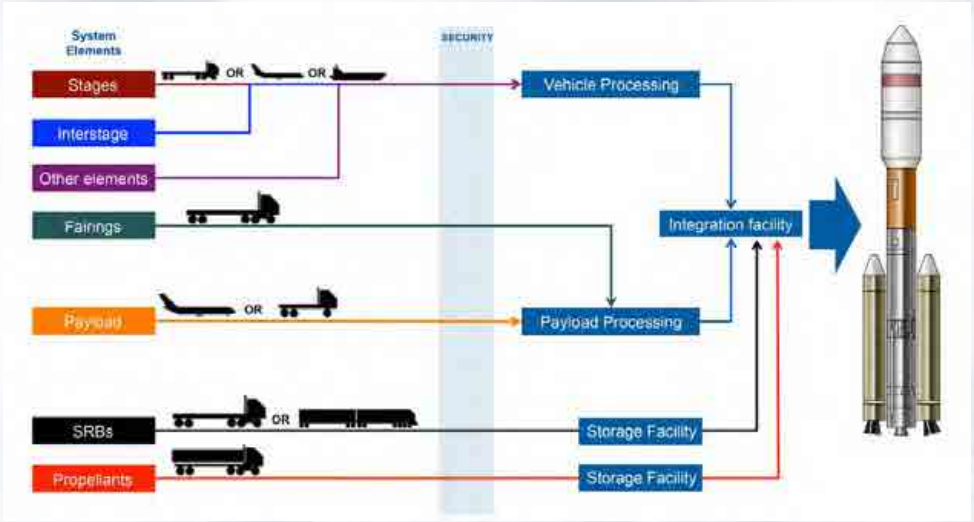
Ground Support Infrastructure

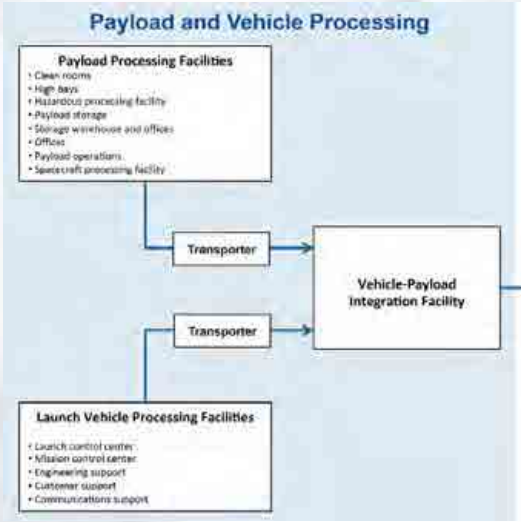
Ground and orbit-based facilities are indispensable elements of space transportation systems; their characteristics, capabilities, interfaces, and costs and limitations are as critical to understand as the launch systems themselves.

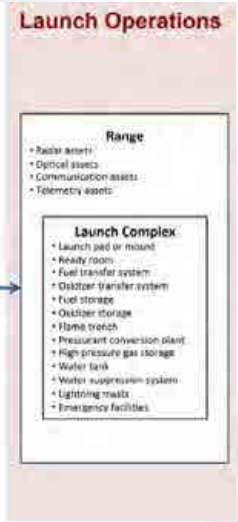
Dependency on a highly specialized ground infrastructure could be a serious constraint to adoption of global space transport as a viable means of transportation for conducting globally integrated mobility operations.

Vehicle, Payload, & Launch Processing

Traditional Model







Source: AST Annual Compendium of Commercial Space Transportation: 2018

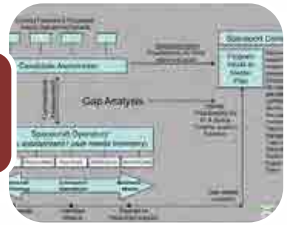
Type of Ground Support Facility

Understand the criteria for choosing type of space support facilities

Space transport system concept of operations

Airfield dual-use …conversion to spaceport

Gap analysis for space transportation vehicle concept of operations versus existing ground support facilities: (mature base, remote base, austere site)



Facility Driven Constraints

Functions required of ground support facilities for space transportation launch vehicles can induce facility-driven constraints

Configuration, preparation and integration of DoD cargo as a payload

Cargo compatibility considerations for launch vehicles, ground facilities , and equipment

Influence on ‘standard containerization’ for ease of transport between modes (e.g. HCU-6E/463L)

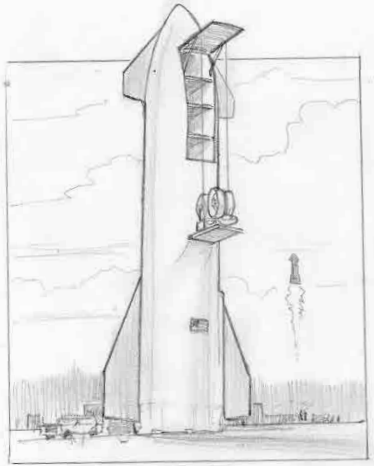
Material Handling Equipment (MHE)

- MHE: Nearly all strategic lift require Material Handling Equipment (MHE): Loaders/Unloaders, nets, dunnage
- AGE: Nearly all strategic lift requires support equipment such as lights, generators, start carts
- MX: Lift requires maintenance and fueling
- Civil Engineering: Nearly all strategic lift requires some level of pre-preparation
- Forward C2: Nearly all forward operations require positioning of a command and control element with C2 personnel, porters and maintainers

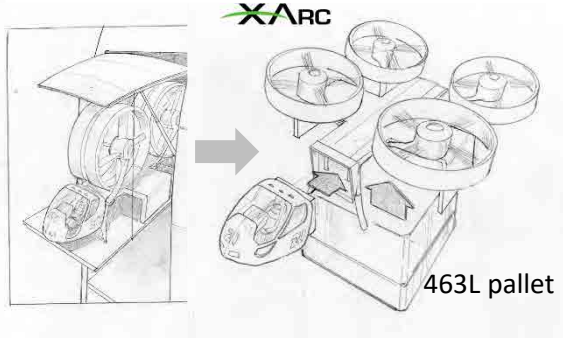
Mission Dedicated Equipment

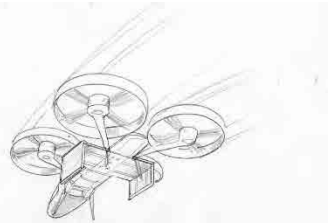
- System deployed as a dedicated equipment included with the spaceship or as part of common-use ground support infrastructure at the base
  - Generic cargo/ utility eVOTLs can be pre-deployed for operation on a remote or mature base as part of common use ground infrastructure

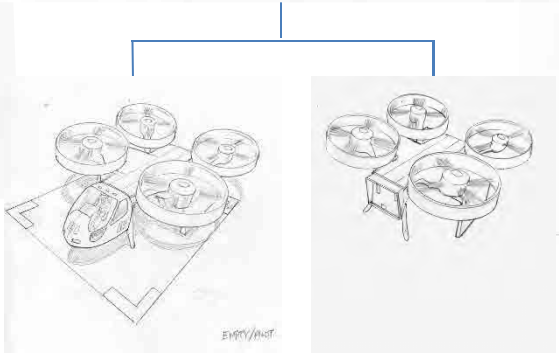
Off-loaded via hoisting platform



Reconfigurable eVTOL Cargo Handler







Piloted Cab Configuration

Autonomous Configuration

Light tactical vehicles

Framework of Ground Logistics

1. Site Preparation/Reception
2. Payload Handling
3. Craft and Crew maintenance
4. Refueling
5. Onward Distribution of Payload

Applicable to all basing scenarios – Prepared Base, Semi-prepared Base, Auster Base

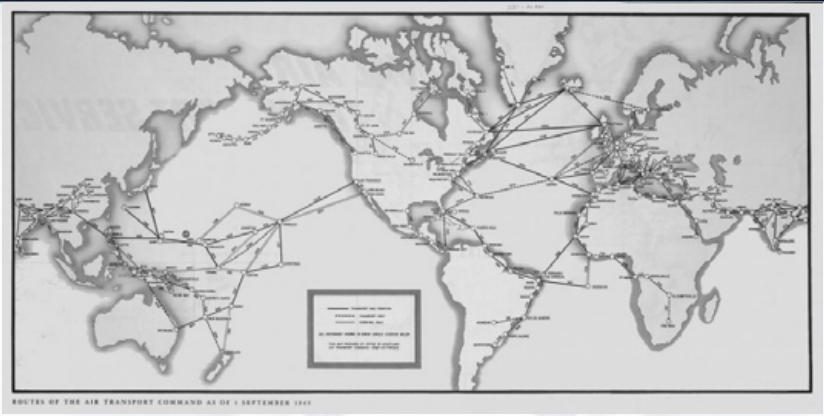

Basing Considerations

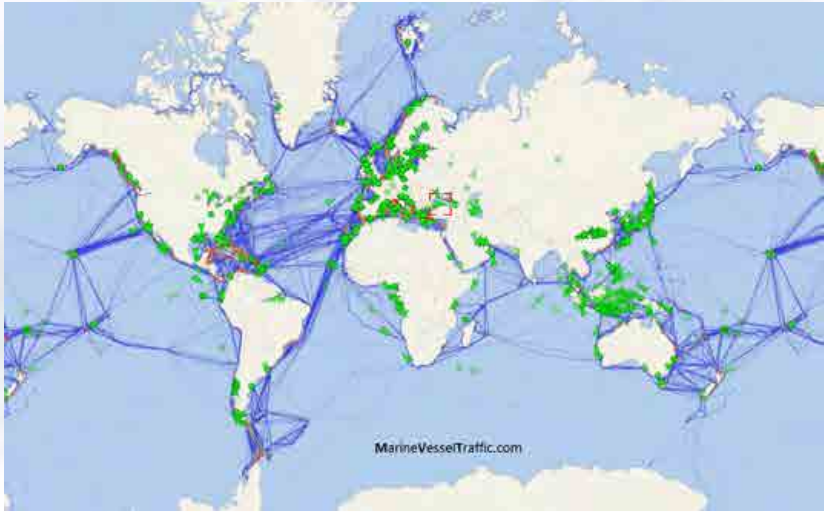
Strategic Considerations for Spacelift

- What are the criteria to questions such as:
  - Where could a Spaceport enable access otherwise impossible? (land locked, or blockaded like Qatar)
  - Where could a Spaceport cut the time-response the most?
  - Where could an intermodal Spaceport significantly cut the response time for several locations?

Strategic Criteria to *Maximize*

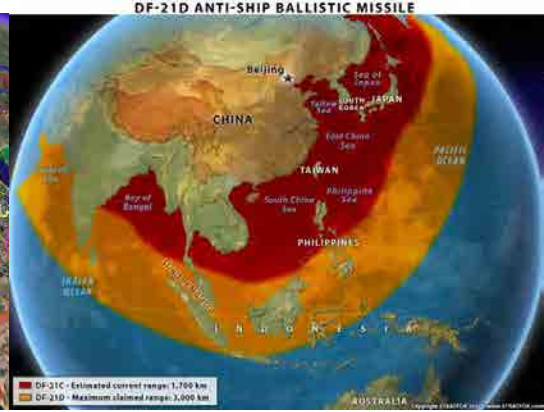
- Synergistic with TRANSCOM enroute structure
- Able to help in areas conflict is most likely
- Be within <2 hrs of most population
- Close enough to support existing bases of operation
- Near cruise ship LNG terminals for inexpensive access to fuel
- Proximate to intermodal facilities (seaports, airports, rail heads, trucking)
- In international waters or in friendly Exclusive Economic Zones (EEZs)





Strategic Criteria to *Avoid*

- Avoid the Most Heavy Air Routes
  - Why? Because serious impact of closure of major air traffic
- Minimize Unfriendly Air Defense Identification Zone (ADIZ) interaction
- Minimize Footprint in Heavy Missile Corridors where possible
- Minimize Footprint in Heavy Anti-Air/BMD zones



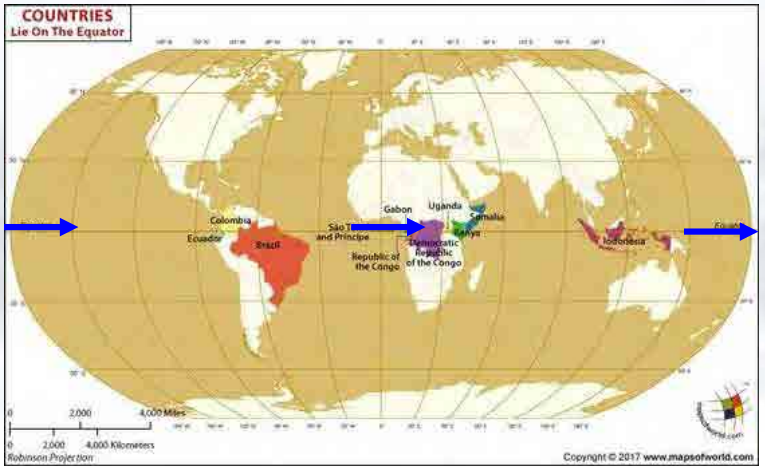
Geopolitical Considerations

Command and control of space transportation facilities including infrastructure resilience against vulnerabilities and threats.

Strategic Importance of Bashi Channel

Special Utility Considerations

- May be particularly attractive to Landlocked States
- Ideal strategic spacelift locations lie at the equator for land or sea-based launch
- Arm Control Treaty Interactions
- Launch and Landing Noise and Hazard & Environmental impact Considerations
- CRSF / Commercial Lift
  - Rather than own, TRANSCOM most likely to purchase commercial spacelift; Commercial Reserve Space Fleet analogous to the Civil Reserve Space Fleet (CRAF)



Security and Infrastructure Overlap

- Overlapping issues in terms of security and infrastructure
  - Supply operations for commercial and DoD is site dependent
    - e.g. SpaceX owned and operated vs DoD as anchor tenant
      - who will be securing the spacecraft
      - who is providing the on-ground logistics
      - how much ground infrastructure provided by SpaceX vs DoD

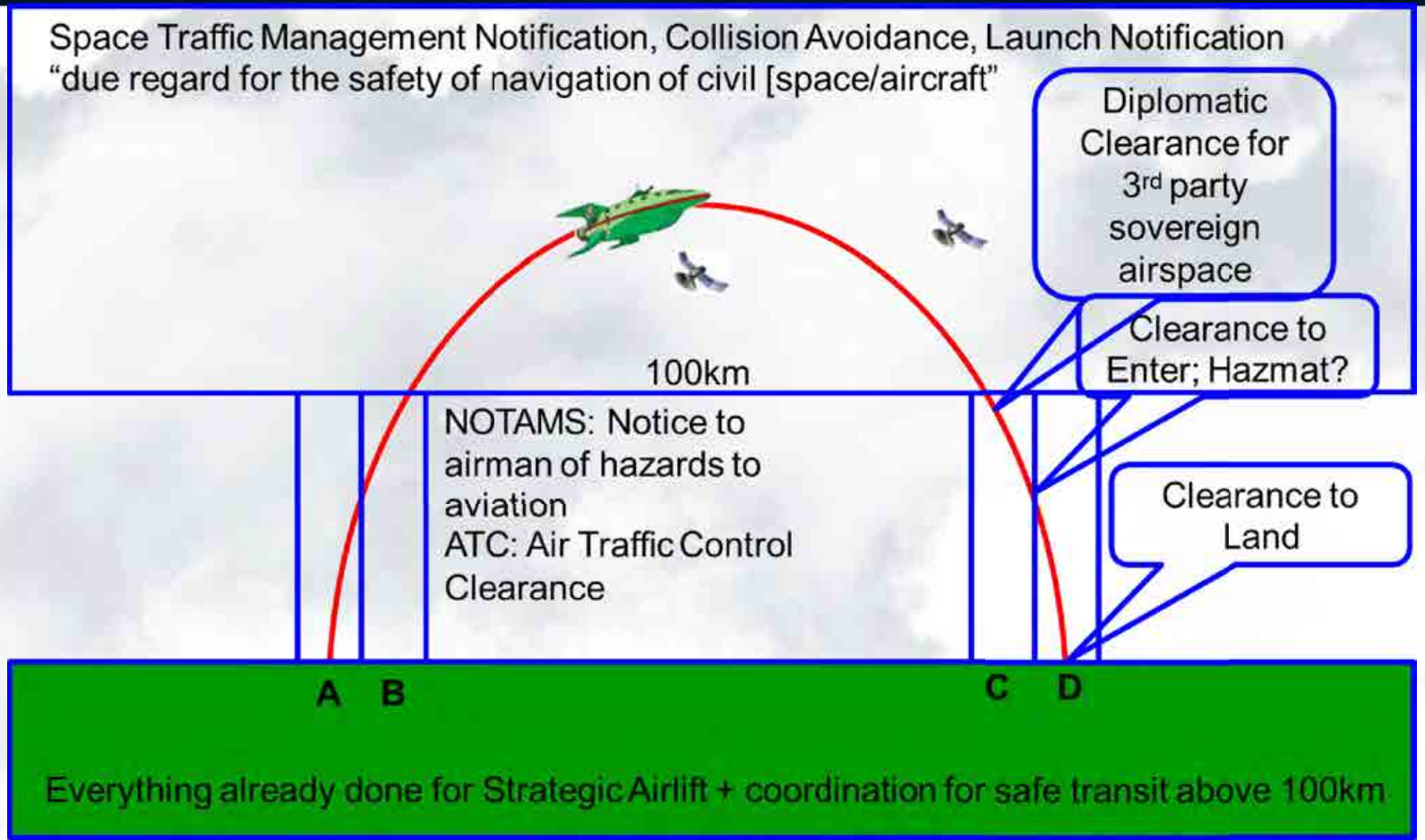
Commercial Market Operations vs. DoD Operations

Mature Site **Evolutionary Approach** Trade Space

Ops Type	SpaceX Commercial Use Site	Joint Commercial/DoD Use Site	DoD Exclusive Use Site
Securing the Spacecraft	SpaceX personnel	SpaceX personnel with DoD oversight	DoD personnel with SpaceX support contractor personnel
Ground logistics	SpaceX Commercial Use Site	SpaceX personnel with DoD oversight	DoD personnel with SpaceX support contractor personnel
Infrastructure Investments	Borne by SpaceX for purpose built facilities	• Augmented by DoD investments • Aviation Airport FBO model, Fixed Based Operator provides ground services to spacecraft operator for fees	• DoD investment (will have to address issues of commercial advantage to SpaceX) • SpaceX investment with DoD as anchor tenant; incentives to locate site at off-market location
Threats	Driven by cost to the operator • What is the threat • What is the fallout • What is the likelihood • What is minimum required to have reasonable level of security	Huge difference between what military can install to protect bases and what commercial can provide and is willing to pay for	
Responses	Decisions driven by fear factor, shock effect, negative publicity		Full throated
Threat Mitigation Architecture	• Personnel on the ground, sensors on the perimeter, intel on what likely threat is and likely weapons, countermeasures depending on physical threat that is postulated • Architecture to help organize protection efforts, e.g., security operations centers with platforms, geo fencing around certain facilities like fuel farm, certain areas with higher surveillance; Tailored to likelihood of threats over long term vs short term, intel driven		
Safety & Security	• Sea operations in host country agreements for mitigating against gas leaks, oil leaks, environmental disasters		

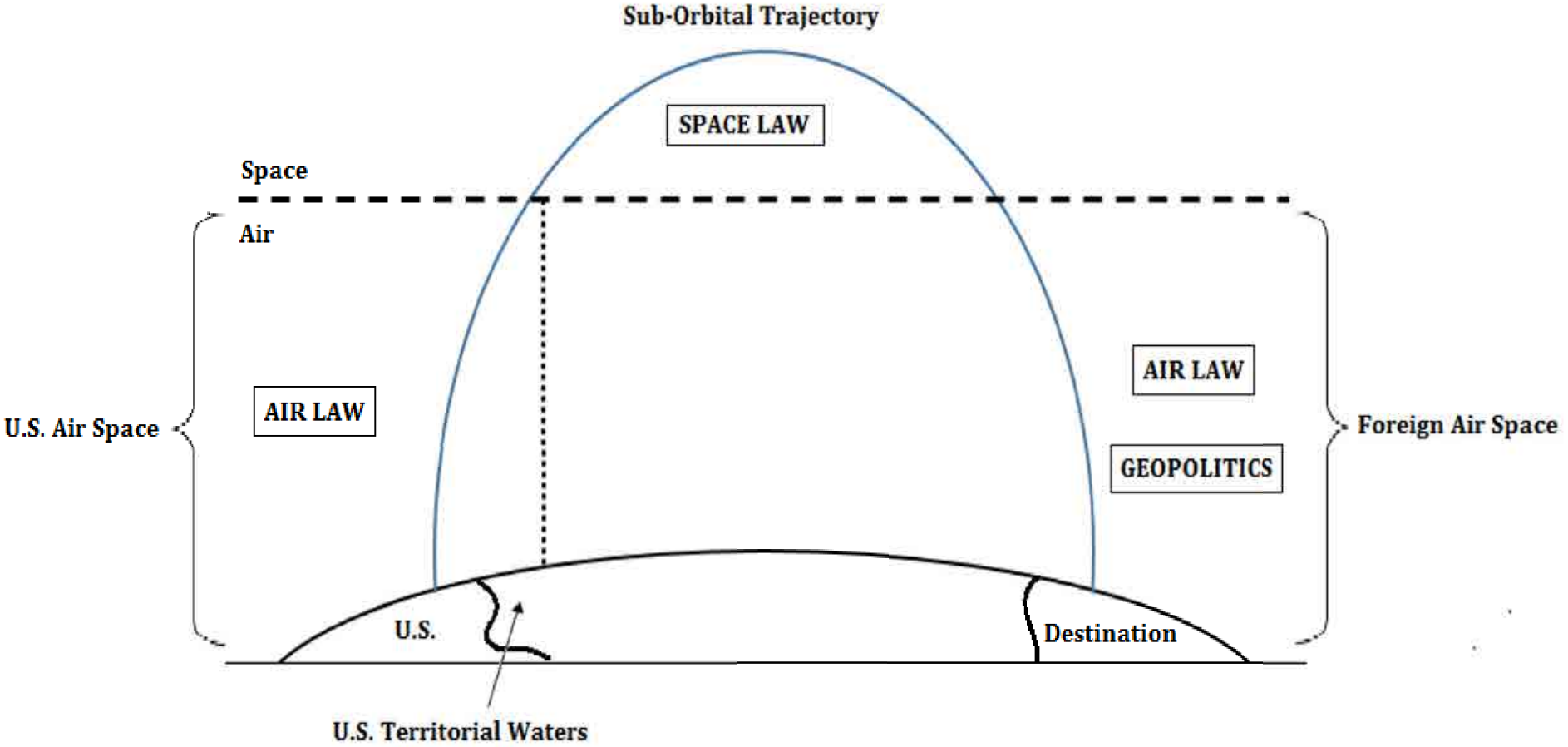
Regulatory Considerations

Flight Regulatory & Diplomatic Approvals



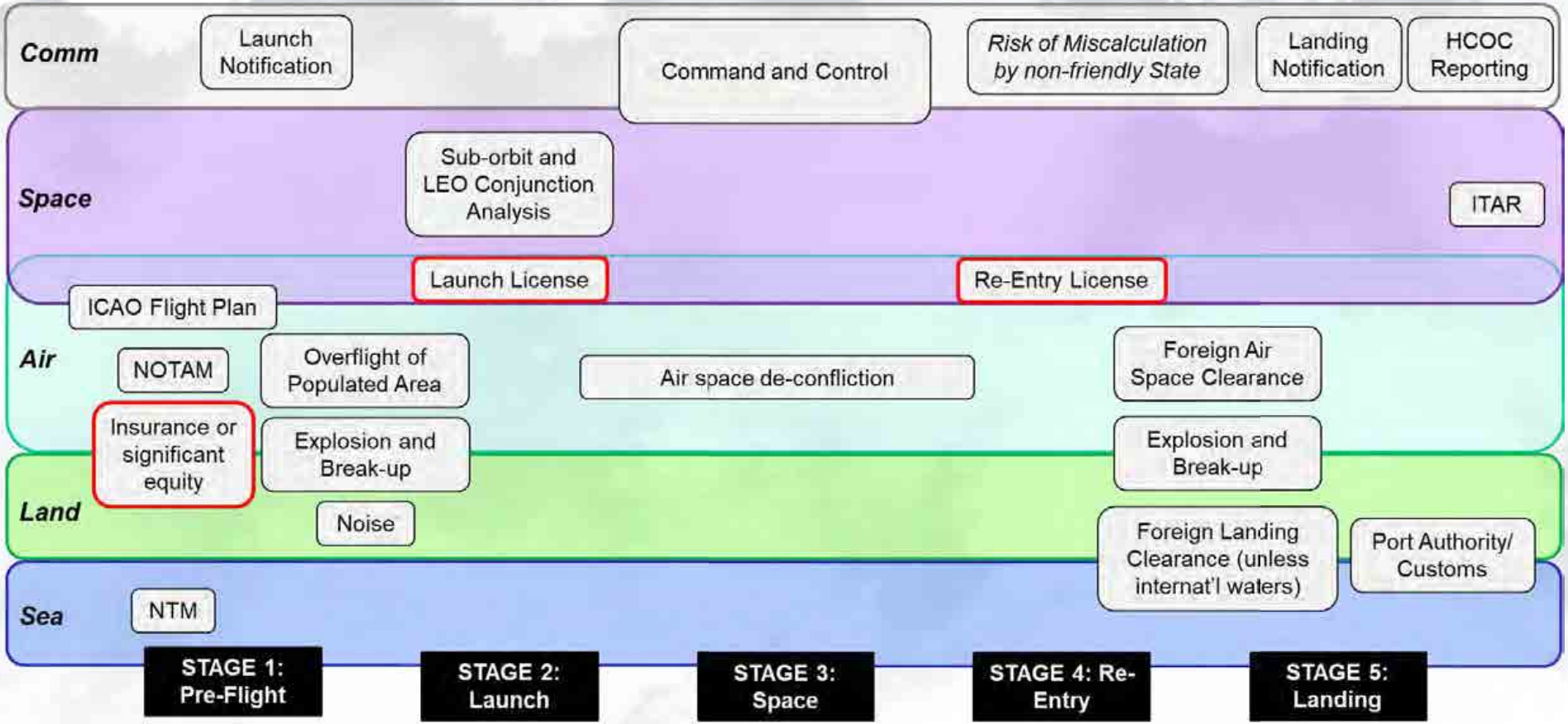
Space Law versus Air Law Regimes

Source: AFIT



Mission Stages

Source: AFIT



Treaties, Agreements, and Legislation

Source: AFIT

- **New START** *[expiring Feb 21]*
- **INF** *[withdrawn]*
- **HCOC** – Notification required
- **ABM** *[inactive]*
- **ITAR**
- **Friendly Relations Declaration**
- **PLNS MOU** – Comm for launch
- **UNCLOS** *(inspiration)*

- **UN level Space Law**
  - OST [keyword: PEACEFUL]
  - Moon and Other Celestial Bodies
  - Return of Astronauts Agreement
  - Liability Convention
  - Registration Convention
- **US does not recognize any delimitation between air and space**

Relevant Offices Involved

Source: AFIT

National

- FCC
- FAA
- FAA/AST
- USAF/USSF/USN/USCG

International

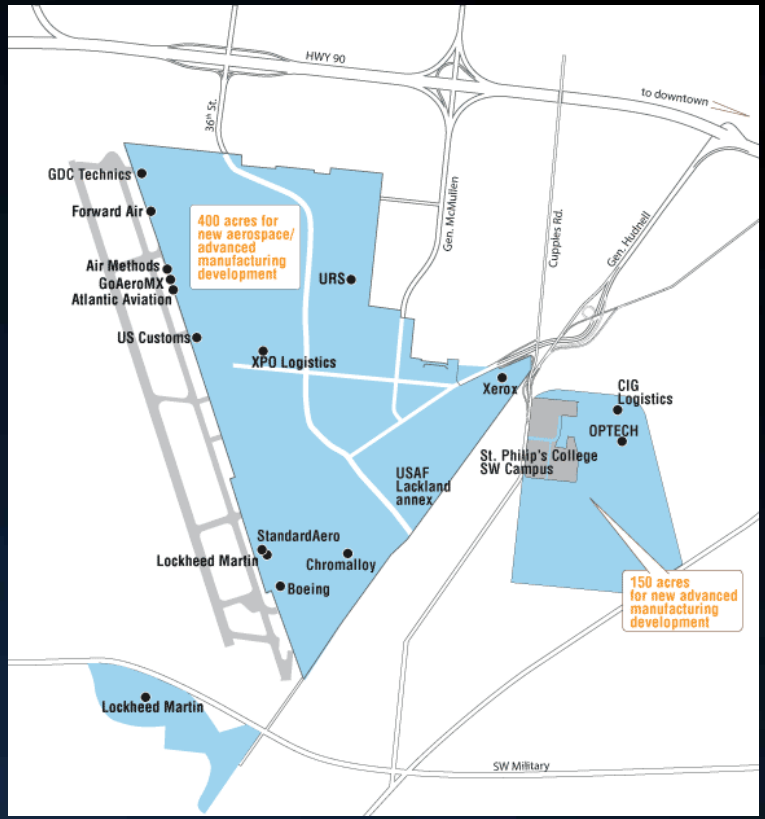
- ITU
- ICAO
- MTCR
- Foreign Military, air traffic control
- UN
  - OOSA
  - COPUOS

Airport/Airbase to Spaceport Conversion Considerations for Space Transportation Basing and Support

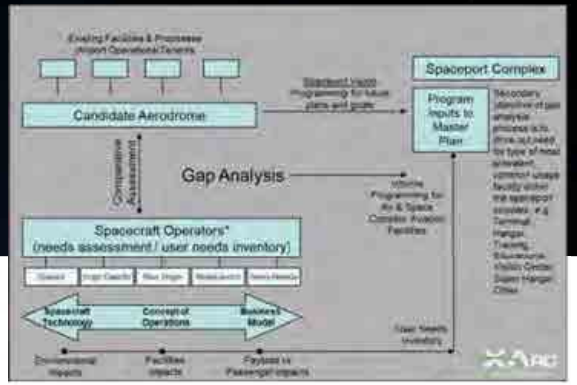
Benchmark with Spacecraft Operators

Transient Operations

Special Use Case



Airbase to Spaceport Conversion – Typical Process



XARC Management

Feasibility Study Project Manager

Spaceport Goals & Objectives	Runway Capability Review	Preliminary Explosive Siting	Support Infrastructure Review		Airspace Compatibility Review	Preliminary Environmental Review
Spaceport Development Process	Runway, Taxi, & Service Road Descriptions	Potential Propellants	Infrastructure Inventory	Planned Expansion & Development	Airspace Overview	Licensing Requirement
Considered Launch Vehicles	Runway Length & Type	Storage of Propellants	Facilities Assessment	Availability of Support Facilities	Proposed RLV Operating Area	Air Quality
Existing & Planned Candidate Spaceports	Runway Expansion/Modification	Preliminary Explosive Site Plan	Tenant Facilities & Services	Required Facilities	Proposed RLV Departing & Arrival Routes	Noise & Compatible Land Use
Potential Spaceport Uses		Explosive Site Plan Evaluation	Other Airport Facilities & Services	Optional Facilities	Alternate Landing Sites	Hazardous Materials
ROM Cost Estimates & Development Schedule			Aircraft Storage & Parking	Support Facilities Evaluations	Orbital Launch Evaluation	Construction Impacts

Questions and Discussion