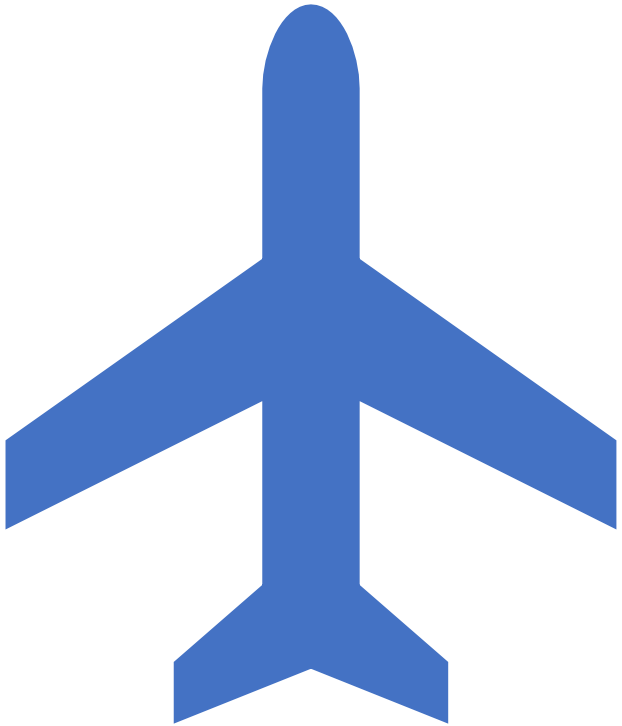

Aerospace Supply Chain and Manufacturing

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NASA Workshop

February 4-5, 2020

Outline

Welcome

Workshop purpose

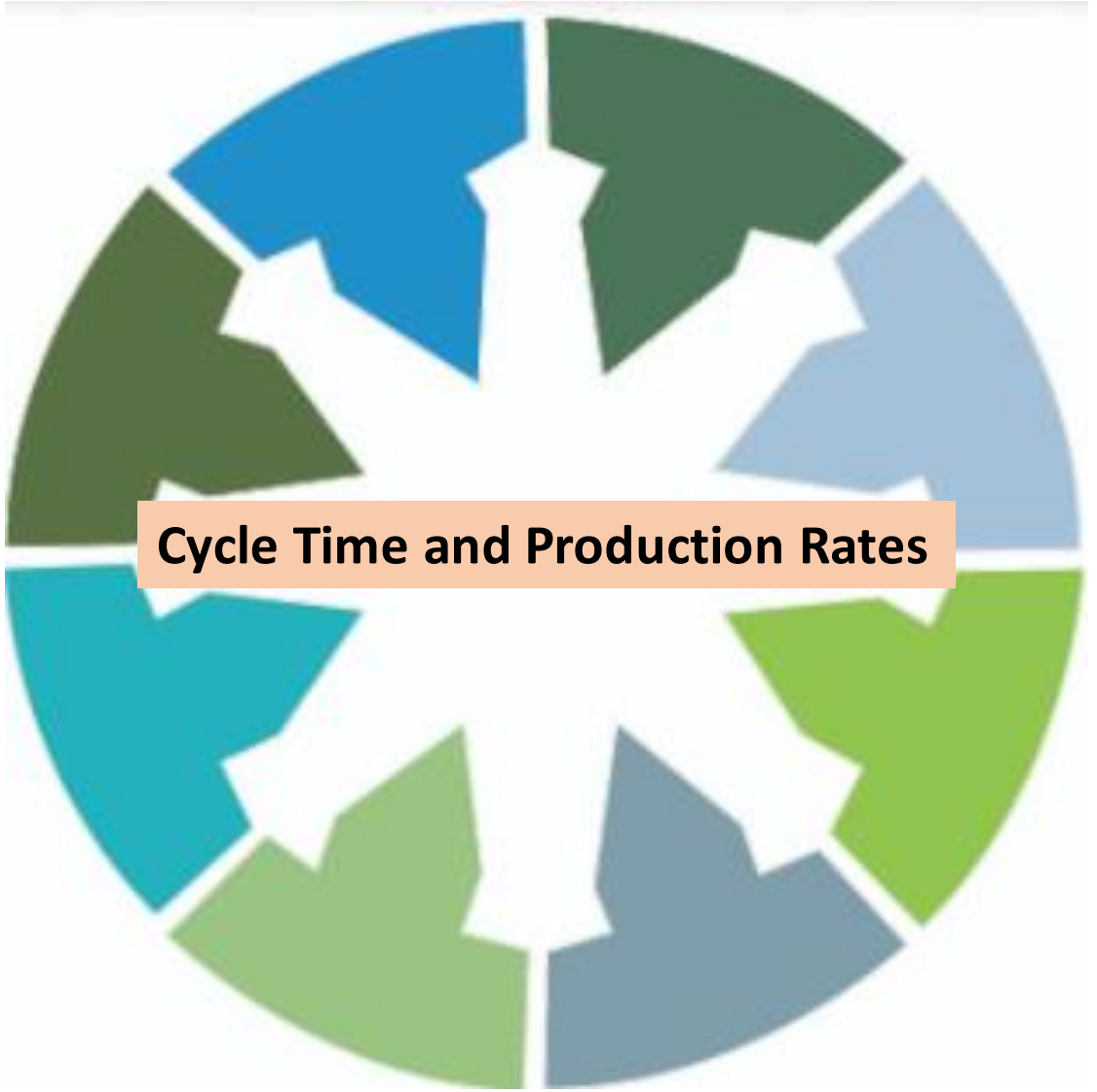
Current Gaps and Challenges

Opportunities

Collaboration and next steps

Welcome

Grateful for your passion around one of the largest barriers in aerospace



Supply Chain Basics

Supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer need

Aerospace supply chain is an ecosystem of different supplier tiers

Includes manufacturers, suppliers, transporters, warehouses, etc.

Supply chain management refers to coordination of all activities

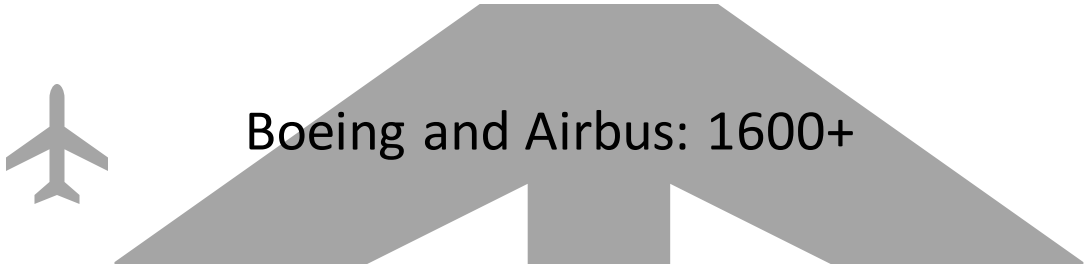
Supply chain impacts entire life cycle from early conceptual design to high volume manufacturing

- All types of aircraft in all phases
- Maintenance, repair, and overhaul
- Skills and talents

Job Search

- Boeing
- Pratt Whitney
- Airports
- Vimana Robotics
- Zipline
- Joby Aviation
- Collins
- Aircraft Propeller Services
- Many more
- 75000+ jobs for all industries

Basic Statistics on Manufacturing



Boeing and Airbus: 1600+

General Aviation (piston, turboprop, business jets): ~2000

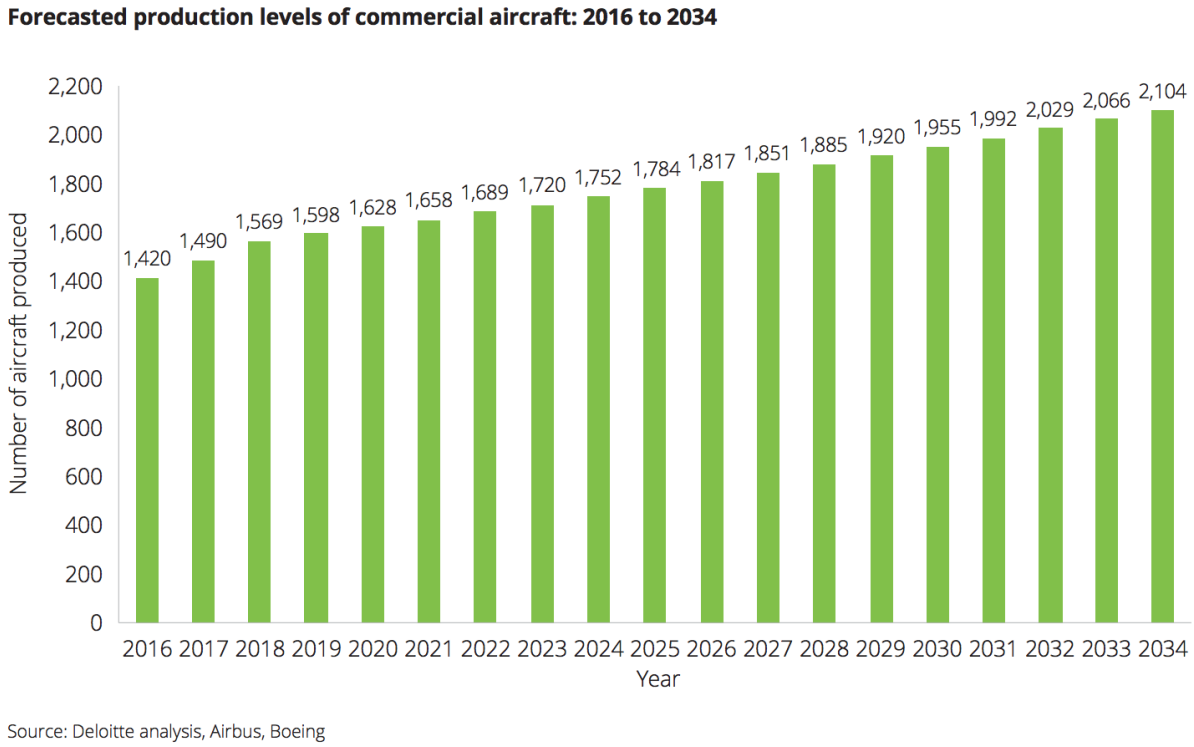
Rotocraft: 1020

Cars: 70M (OICA, 2018) Cars in US: 2.8M

Conventional Aircraft

Current Situation ($800+B backlog)

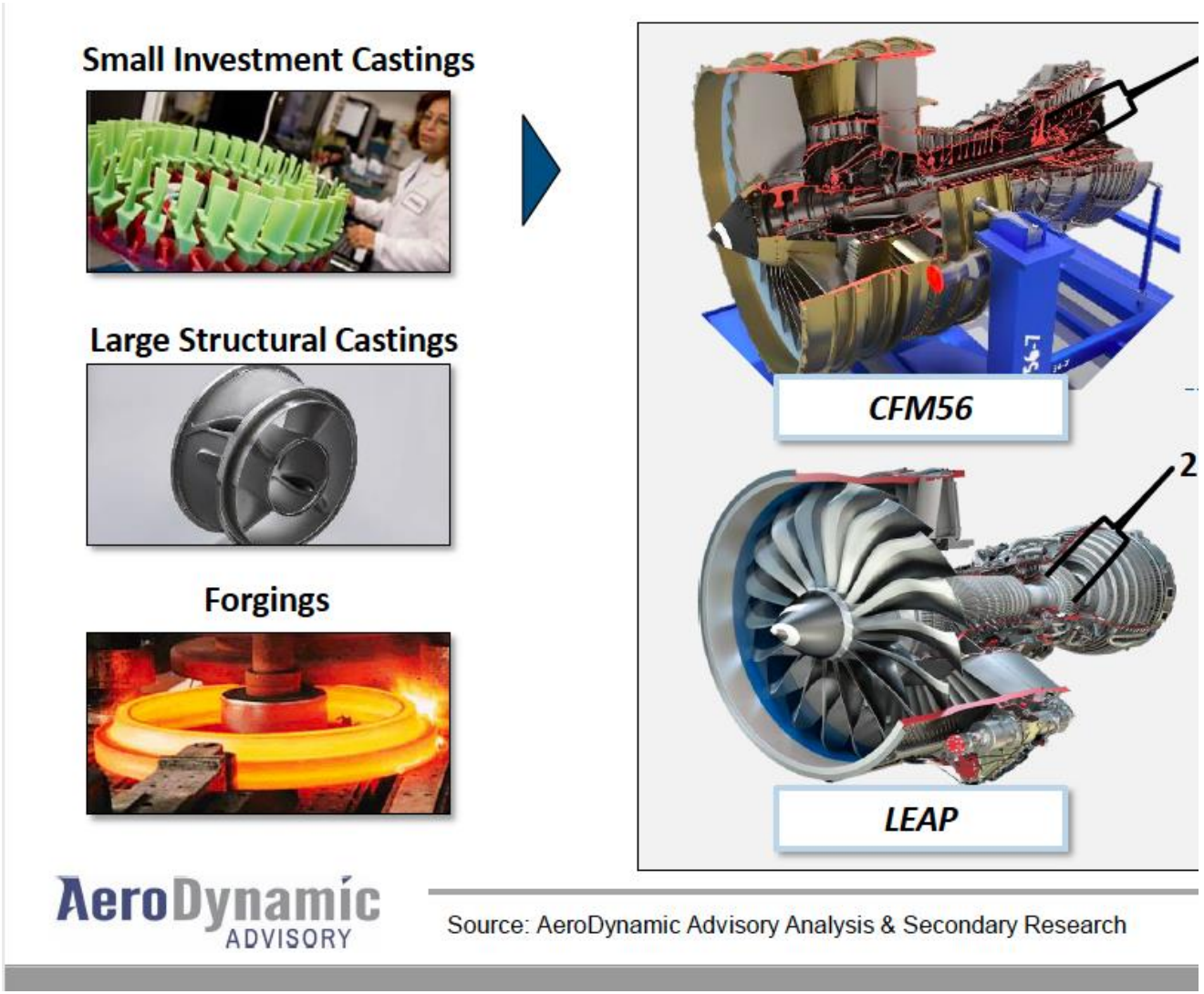
- Boeing and Airbus have backorders (~5000+, with ~55/month rate)
  - Boeing delivered 806 aircraft and Airbus 800 in 2018
  - Airbus 863 (2019, 7% up)
  - In 2016, Boeing had 5715 undelivered orders and Airbus had 6874



Source: Deloitte analysis, Airbus, Boeing

Challenges

- Casings and forging
- Composites
- Auxiliary Power Units
- Printed Circuit Boards
- Actuators
- Software
- High volume manufacturing and assembly methods
- Many others



Supply Chain Considerations and Challenges

(Credit: EY – A&D Edge, Supply Chain Management in Aerospace and Defense, Feb 2018, slides 8-9)

	Design and Engineering	Planning	Procurement	Manufacturing	Aftermarket
Considerations	• Timeline • Cost • Quality • Margin • IP • Efficiency	• Forecast accuracy • Supply disruptions • Demand shifts • Inventory • Supply chain visibility • Lead times	• Supplier performance • Price volatility • Cost and prices • Lead times • Supplier due diligence	• Quality • Stock-outs • Waste • Capacity • Cost • Contract • Safety • Volume	• Ground time • On-time delivery • Network • Safety
Challenges	• **Dependence on large number of sole-source suppliers** • **Long lead time** • **Financial challenges across the supply chain for new programs** • **Large inventory needs** • **Collaboration across complex supply chain** • **Cyber and security**				

Strategy	Dependence on sole source suppliers	Long lead time	Financial challenges	Large inventory	Collaboration across supply chain	Cyber threats
Adoption of digital technologies	Moderate	High	Low	High	High	High
Risks-sharing partnerships	Low	High	High	High		
Integration	High	High	Moderate	High	High	Moderate
Monitor security	Low				Moderate	High
Cross-sourcing	Low	High		High	Moderate	
Multiple sourcing	High	Moderate			High	
Readiness assessment		High		High	Moderate	
Local players in supply network		High		Moderate	Moderate	Low

Credit: EY – A&D Edge, Supply Chain Management in Aerospace and Defense, Feb 2018)

Similar challenges for electric or hybrid, supersonic, and hypersonic aircraft – may be even worse

Drones

DOD looks to expand drone industrial base amid supply chain concerns

By Lauren C. Williams | Aug 26, 2019

Summer Internship Project:

Hard to find all supplies quickly that will satisfy NASA and other government needs

Drone industry needs sustainable supply chain and manufacturing capabilities

Vertical Take-off and Landing

Needs

Many calls, texts, and interactions about looking for suppliers and manufacturers

Overmolding

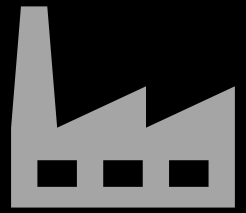
Actuators

Electric motors

Propellers

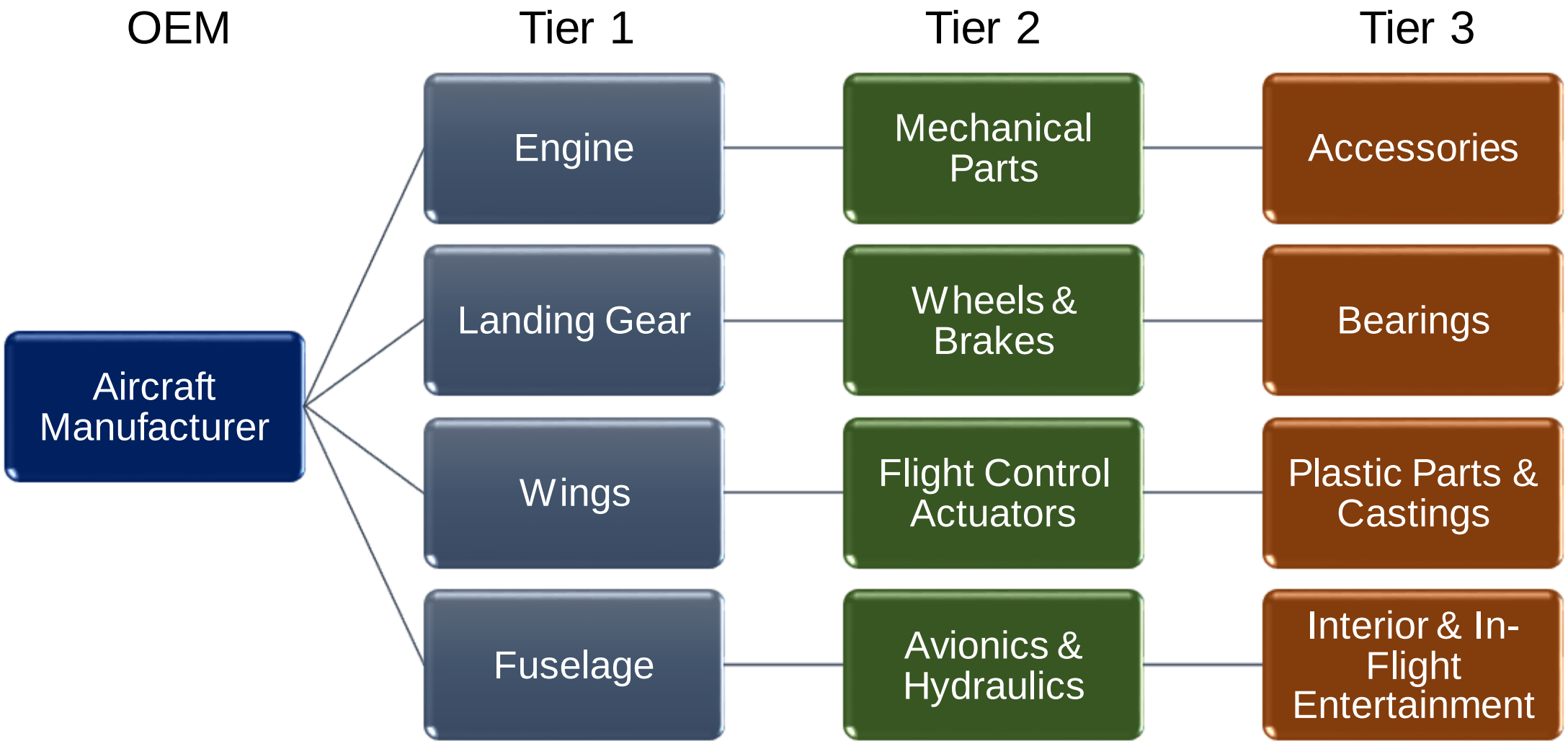
Casting

Many other components and manufacturing needs



Need suppliers for entire life cycle:

Design to high volume manufacturing



- **OEM** – Control design, manufacturing and assembly function, the most critical component of value chain
- **Tier 1** – Support Primes by providing them with equipments and systems like engines, Wings, Fuselage
- **Tier 2** – Manufacture and develop parts as per the specifications provided by primes and Tier 1 suppliers
- **Tier 3** – Responsible for supplying basic products, components and other non-core value added services

Source: https://www.tresvista.com/wp-content/samples/landscaping/Research%20Report_Aerospace%20-%20Supply%20Chain%20Overview.pdf

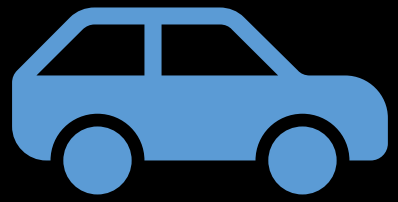
Opportunity to create a tiered system for eVTOLs

Maintenance, Repair and Overhaul (MRO) Market

- Global industry: $80+Billion
- Network needed for eVTOLS

Outlook

Need sustainable supplier, manufacturer, and MRO network



Car companies are entering aero industry

Need to understand the production certificate, and aviation grade manufacturing needs

Putting it all together

Current State of the Art: Risk Archetypes

- Limited/sole sources
- Fragile supplier and market
- Capacity constrained supply market
- Foreign dependency
- Diminishing manufacturing sources and material shortages
- Gap in U.S. human capital
- Product security

Executive Order

- Assessing and strengthening the manufacturing and defense industrial base and supply chain resiliency of the United States
- Executive order 13806, September 2018
  - Decline of U.S. manufacturing capabilities and capacities
  - Competitiveness
  - Diminishing STEM and trade skills

Supply Chain Strategies

Reference: Operations Management, Heizer et al (2016)

- Many suppliers
- Few suppliers
- **Vertical Integration**
- Joint Ventures
- Horizontal Integration
- Keiretsu Networks (part collaboration, part few suppliers, part vertical integration)
- Virtual Companies

Known Aero Supply Chain Related Issues (California Manufacturing Network, 2018)

Sourcing of raw materials – aluminum, steel, copper, etc.

Mitigating supply disruption risks (e.g., geopolitical considerations)

Coping with Modernization and Emerging Technologies (e.g., wiring problems, software issues, late deliveries of lavatories)

Shortage of skilled workers (Tim Cook's view on outsourcing)

Recommendations: Supply Chain for Urban Air Mobility Vehicles

Time to start building an entire new eco-system

Take advantage of other manufacturing (e.g., auto)

Rebuild/train auto, heavy industries, traditional aerospace suppliers to consider VTOL

Get regional manufacturing and supply chain associations exposed to emerging aero needs

Recommendations: Supply Chain for Urban Air Mobility Vehicles

Build an electronic exchange platform to connect VTOL customers with suppliers

- Prototypes
- Job production
- Mass production
- Quality management based on FAA production need

Training workforce: curriculum, skills, and entrepreneurs

Establish tiered system

Establish MRO network

Immediate Success:

Grow emerging aerospace ecosystem

Convert non-aero suppliers and manufactures

Expand current aero suppliers and manufacturers in new areas

See opportunity and identify areas to contribute

Create a tired system and electronic platform for eVTOLs

Conclusions

- Build supply chain and manufacturing base for aero needs – particularly for emerging vehicles
- Support OEMs with supplier and manufacturing base and MROs
- Increase production rate and delivery as compared with today's aerospace manufacturing and assembly state of the art
- Parts access will need to be rapid for MROs
- Build electronic platform with authenticated parts and certified supplier and manufacturer base
- Time to rebuild skills, talents, digital enterprise and attract new manufacturers to scale deliveries

https://arc.cnf.io

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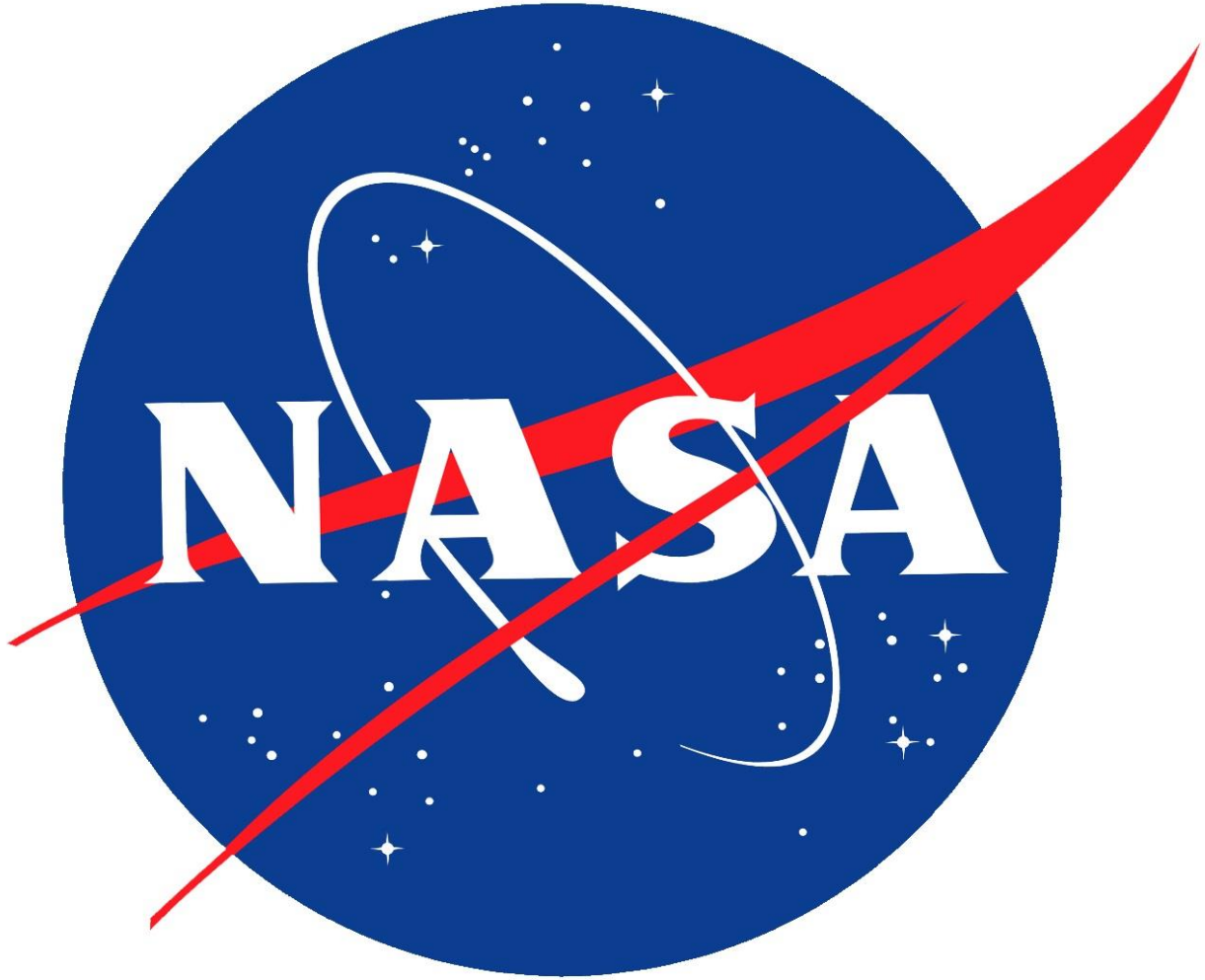


BACKUP

Scalability is Fundamental Need for UAM

- Many pilots (or acceptable and reliable autonomy)
- Spectrum availability
- Airspace operations (e.g., Unmanned Aircraft System Traffic Management type construct)
- Acceptable noise
- **Mass production of electric or hybrid VTOLs**
- **Infrastructure (including recharging systems)**

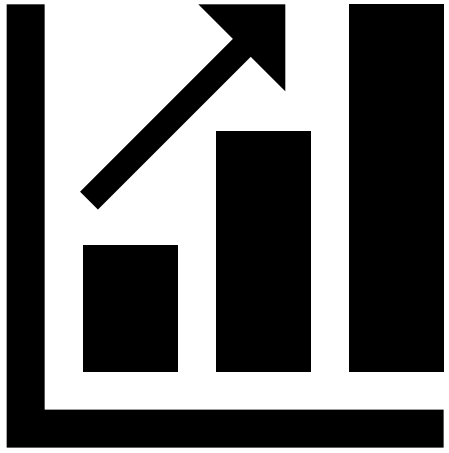
Mass Production of VTOL Vehicles

- Production rates need to be closer to cars than conventional aircraft
  - Manufacturing and assembly methods
  - Supply chain network and ecosystem

Current State of the Art in Aero Supply Chain

Reference: Airbus' Global Market Forecast, Future Journeys 2013 - 2032

- Air Traffic is expected to **DOUBLE** in the next 15 years
- The number of passengers is predicted to rise from 2.9B in 2012 to 6.7B by 2032
- The passenger fleet will grow by 109% from 2012 – 2032
  - **Rising from 16,093 to 33,651 aircrafts**



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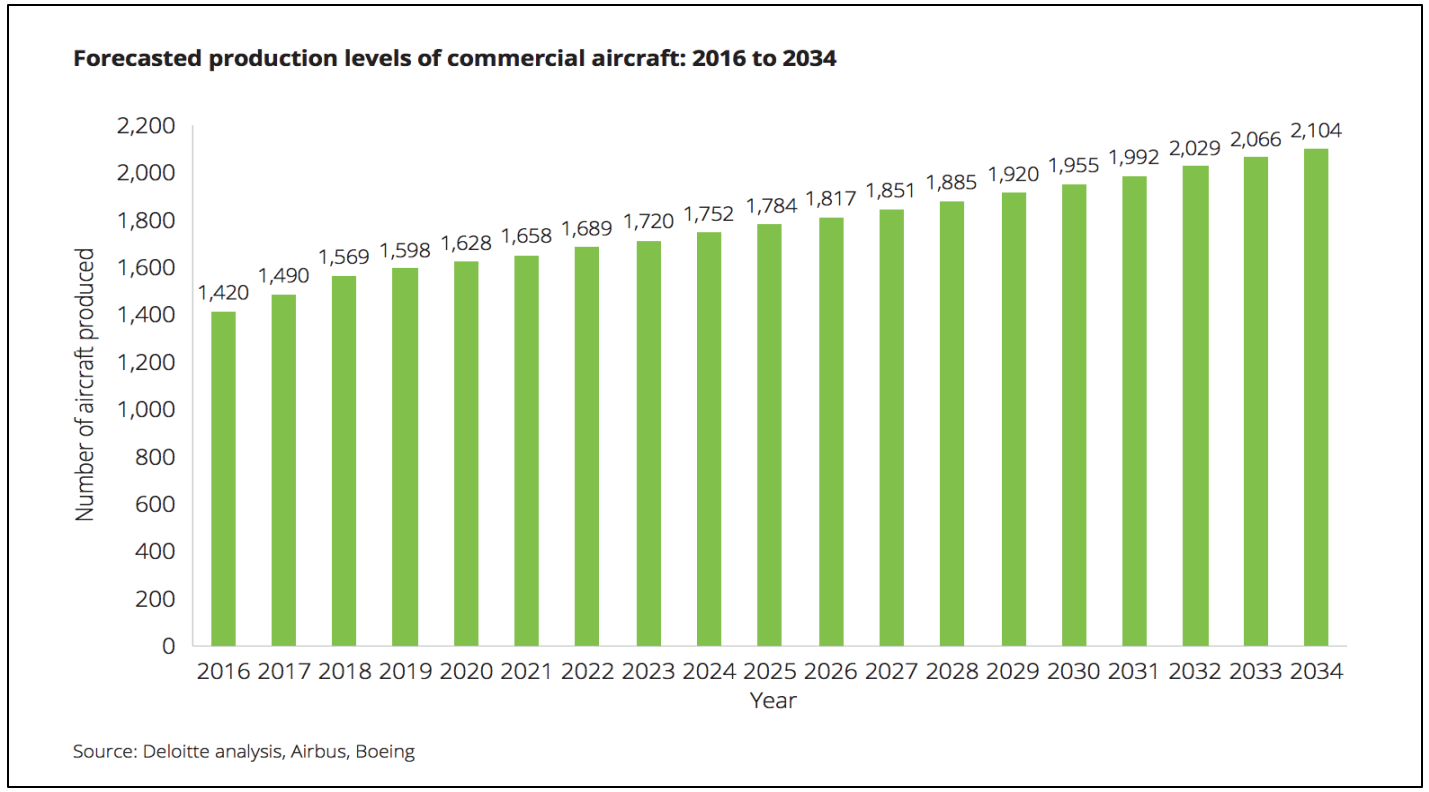

Current State of the Art in Aero Supply Chain

Reference: Oliver Wyman Global Fleet & MRO Forecast Commentary 2019 - 2029

- In 2017, the U.S. accounted for 49% of the global aerospace industry
- The future growth in aviation will be concentrated in Asia and the developing world, **particularly China and India**
  - By 2035, the Civil Aviation Administration of China projects the number of airports in the nation will double
  - By the end of the decade, China will become the biggest global market for air travel and Asia will be the new center of global aviation activity

Current State of the Art in Aero Supply Chain

Reference: McKinsey Quarterly The Growing Role of Emerging Markets in Aerospace

- Due to globalization, the Western companies will capture short-term cost-reduction opportunities
- This provides opportunity to **refocus resources and capabilities on higher-value activities** (specialization of the industry's supply chain)
  - E.g. develop the next clean-propulsion technology or composite assemblies

Strategy	Dependence on sole source suppliers	Long lead time	Financial challenges	Large inventory	Collaboration across supply chain	Cyber threats
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