経済産業省

今後の我が国の航空機産業とCMIへの期待

- Outlook of Japanese Future Aerospace Industry and Expectation of CMI -

2021.10.22

経済産業省 製造産業局 航空機武器宇宙産業課

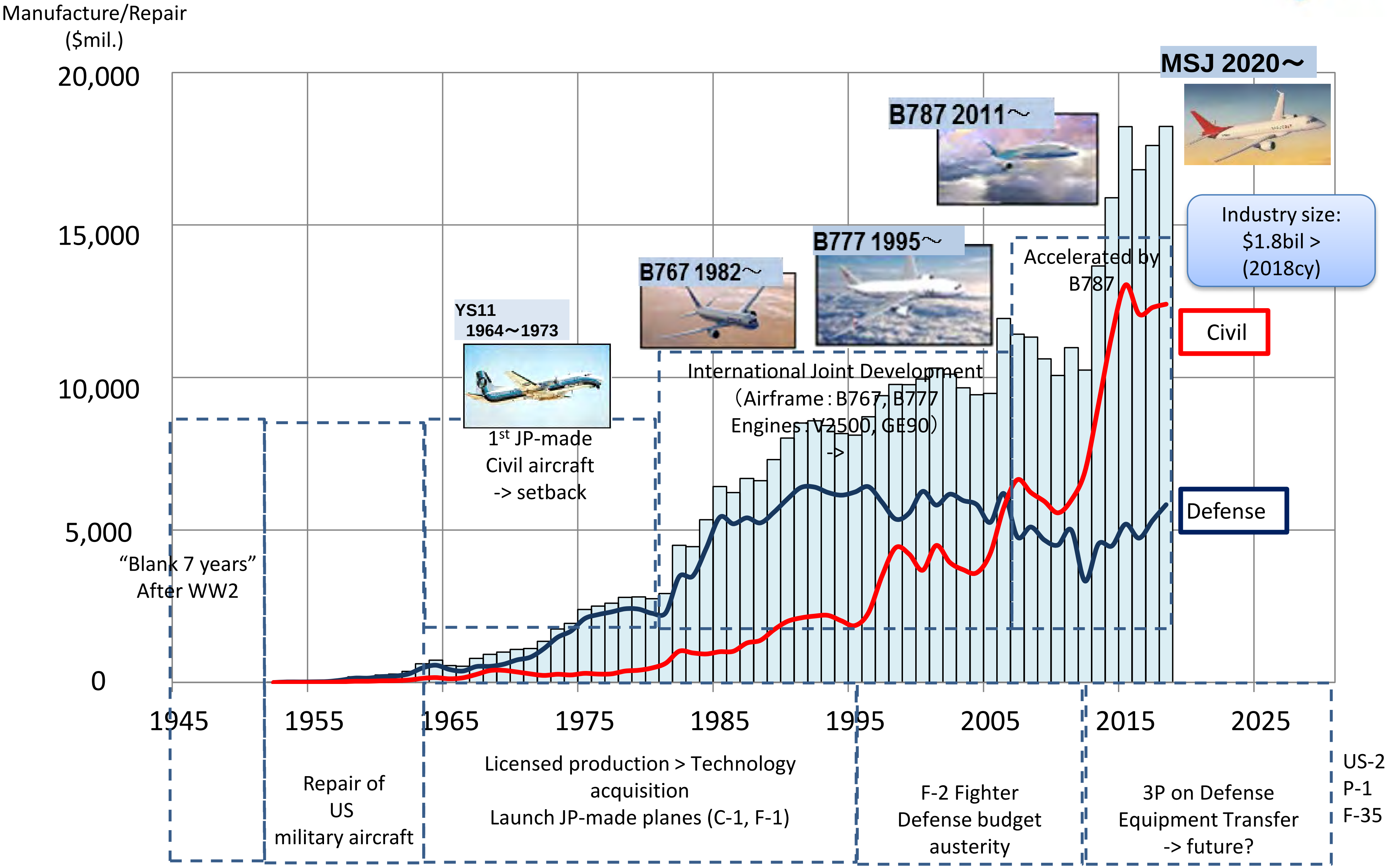
【Today’s Topics】

１．航空機産業のこれまで
- History and Outline of Japanese Aerospace Industry -

２．世界の航空機産業の潮流（市場成長、環境、各国の施策）

３．今後の方向性、経済産業省の施策

History & Future of Japanese Aircraft Industry

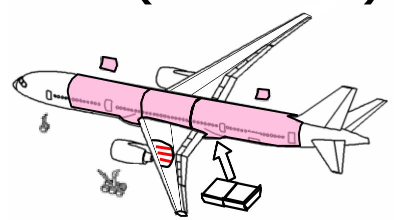


Japan as a Joint Development Partner

- Japan has been participating in international projects working on airframe structure and engine parts for more than 40 years .

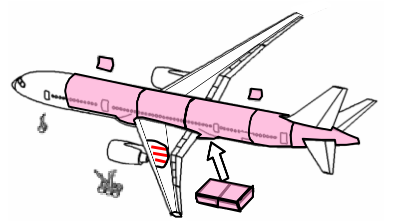
Airframe

B767 (250 seats)



Participation：15%

B777 (380 seats)

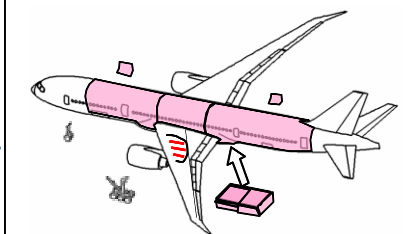


Participation ：21%

B787 (250 seats)

Participation：35%

B777X (400 seats)



Participation：21%

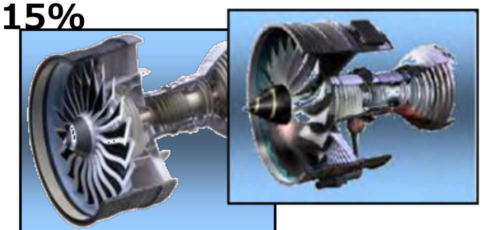
Next Generation

Engine

IAE（JV w/PW etc.）: V2500 (A320 (150 seats))
Participation: 23%

RR:Trent800/ GE: GE90 (B777 (380 seats))
Participation: 9～10%

RR: Trent1000 / GE: GEnX (B787 (250 seats))
Participation: 15%

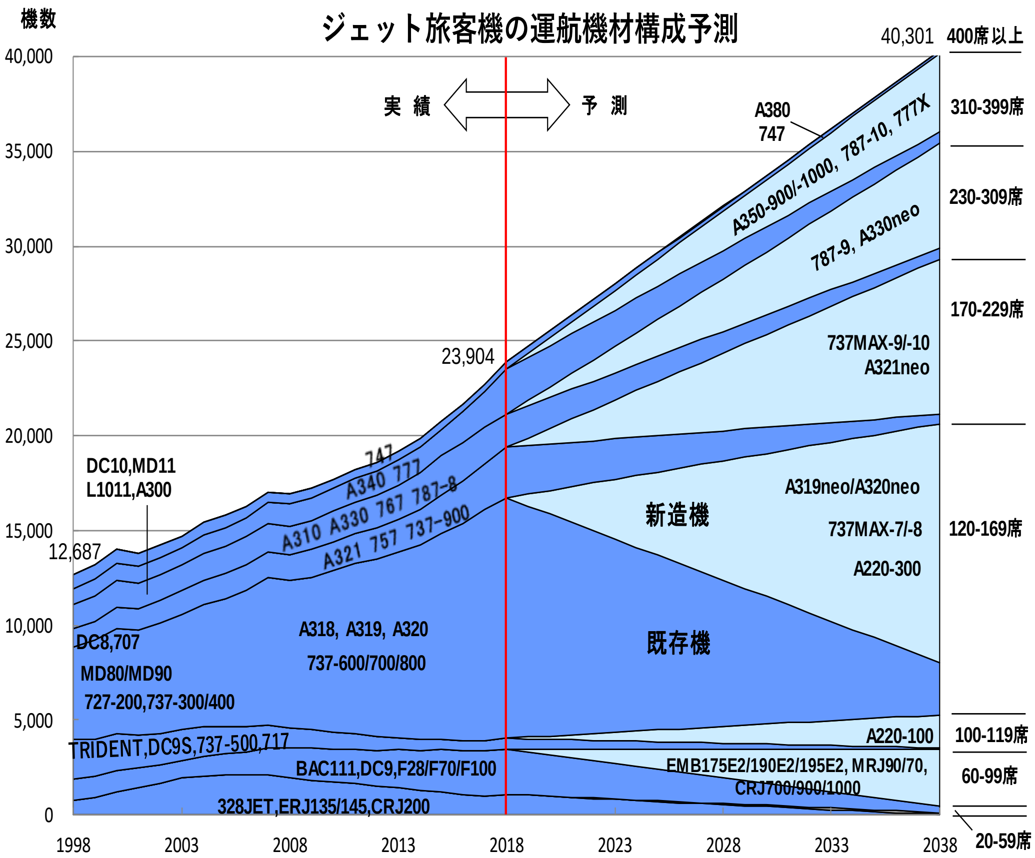


PW: PW1100G-JM (A320neo (150seats))
Participation: 23%

GE: GE9X (B777X (400 seats))
Paritícipation: 10.5%

Prediction of world's aircraft industry - Before COVID-19 -

- Mainly Asia pacific area, demands of air travel were predicted 5% growth continuously. As growth of air travel demands, aircraft manufacturing were also prospected to expand largely, before COVID-19.



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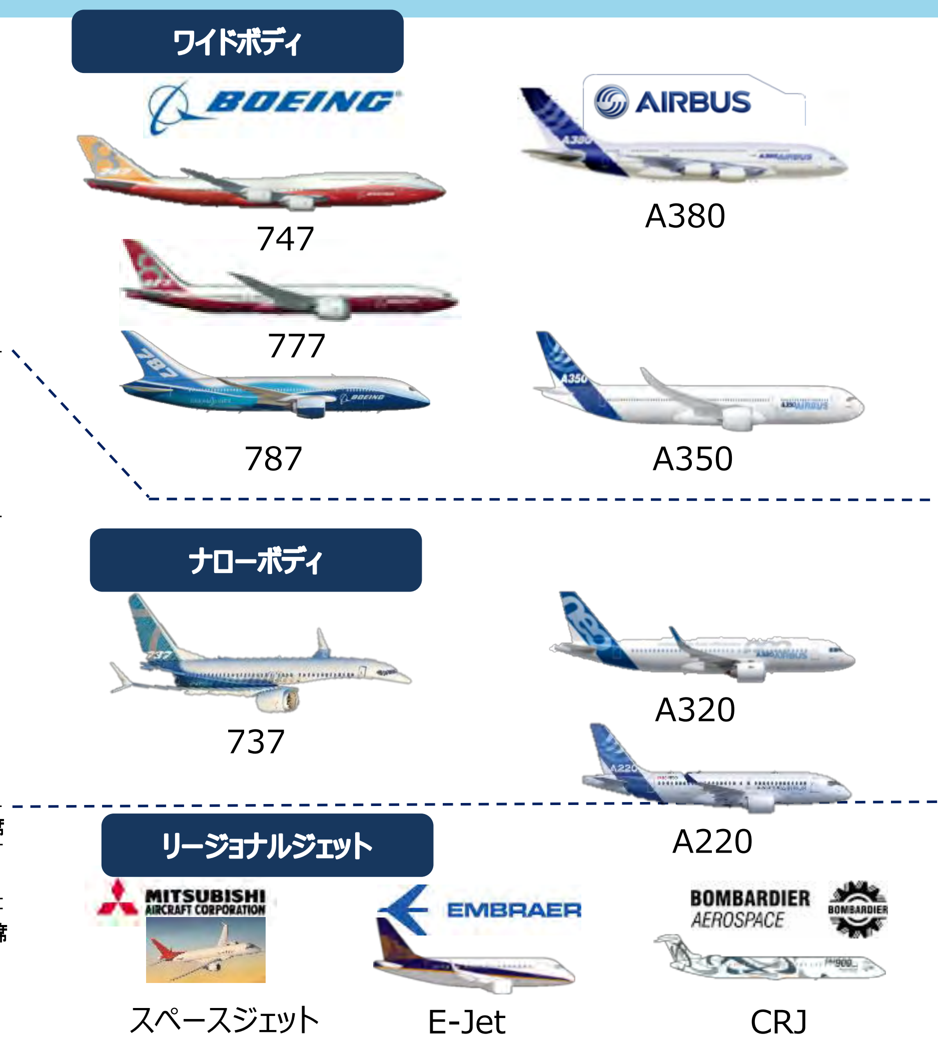


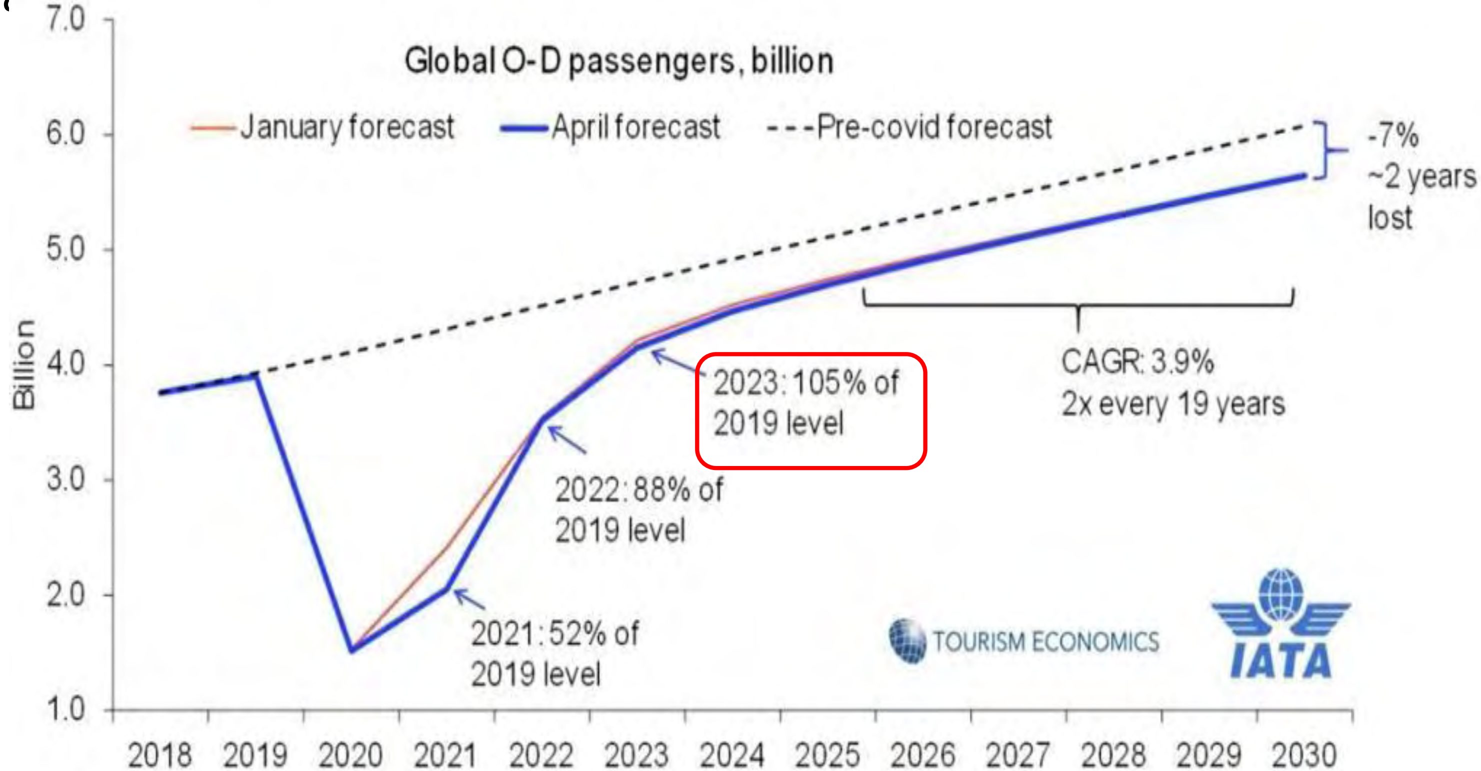
1．航空機産業の歴史

2．世界の航空機産業の潮流（市場成長、環境）
- Trend of World Aerospace Industry
(Market, Environment) -

3．今後の方向性、経済産業省の施策

Impact of COVID-19 on the aircraft industry

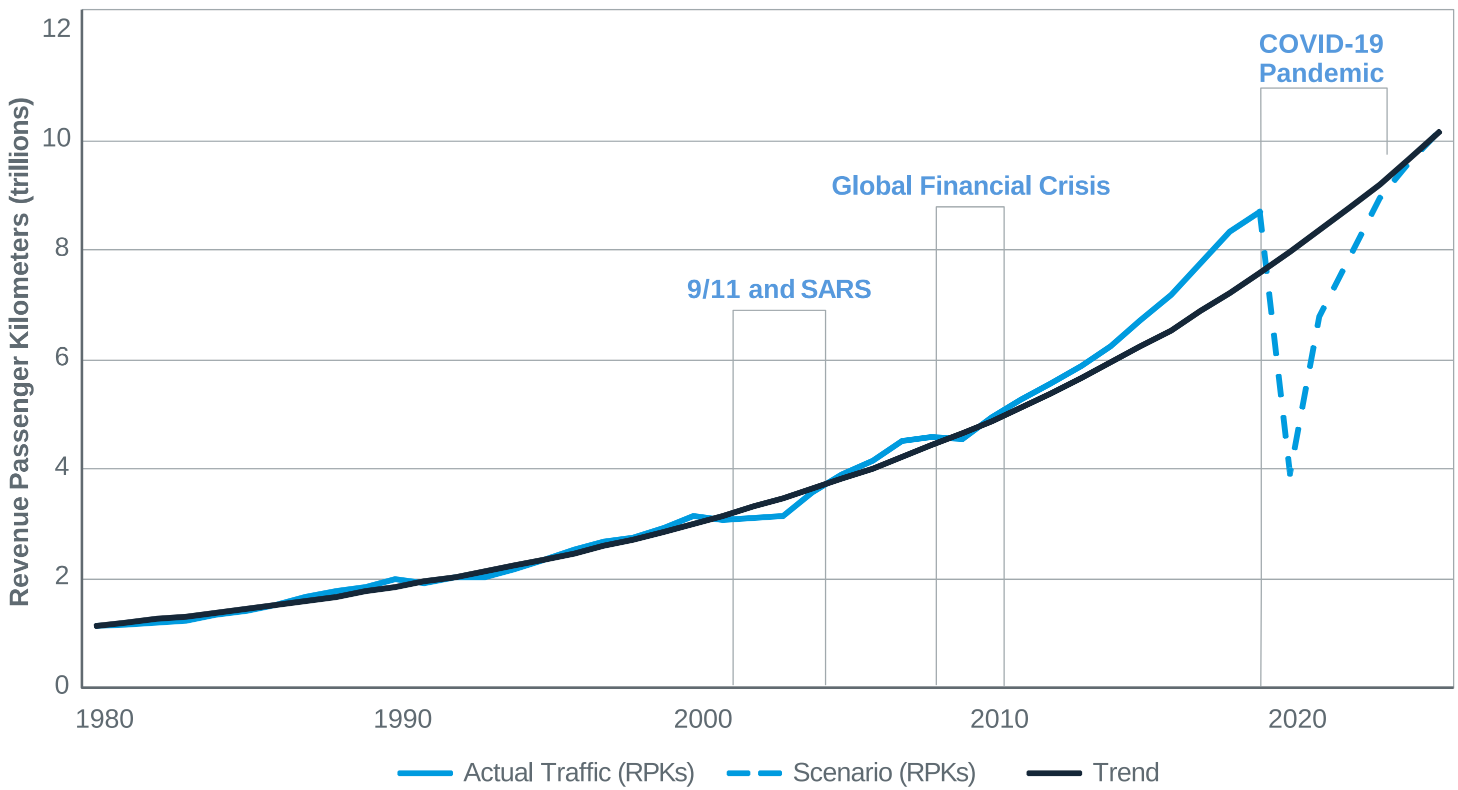
- **Before COVID-19**, global civil aircraft market was prospected to **increase 5% every year**.
- COVID19 caused **sharp decrease** in passenger demand, and significant reduction in production rate by Boeing Airbus etc.,
- Currently **there are signs of recovery in the US and European domestic flights** with the progress of vaccination.
- **Passenger demand is expected to return to 2019 level in 2023**.(revised upward compared to last year)



Source: The International Air Transport Association (IATA, April 2021)

Aviation market demand forecast

- In **September 2021**, **Boeing** announces long-term demand forecast for the aviation market.
- **The forecast for commercial airplanes demand (Fleet)** has **revised upwards** compared to the previous year's forecast, and shows **growth at an annual rate of 3.1% over the next 20 years, exceeding the GDP growth rate (2.7%)**.



ICAO scheduled traffic through 1999 / 2000-2019E IATA stats / 2020F IATA December 2019

Forecast (2021～2040)

3.1% Fleet Growth	**2.7%** GDP Growth
4.0% Traffic Growth	**49,405** 2040 Fleet
2.1M New Personnel	**$9,540B** Services Market Value

Source: Boeing Commercial Market Outlook 2020-2039, 2021-2040 ,September 2021

Impact of the COVID-19 on the Japanese aircraft industry

- The sharp decrease in air passenger demand, significant reduction in production rate by Boeing etc., and also the decrease in maintenance demand for airlines

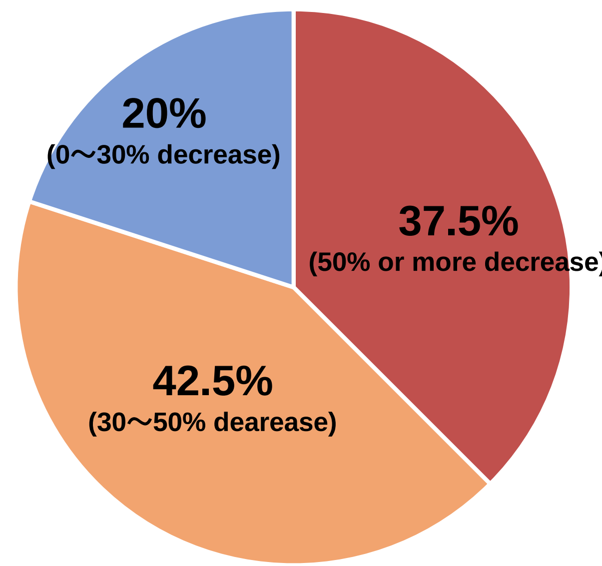
➡ huge negative impact on the whole Japanese aircraft industry and supply chain including SME suppliers and clusters.

■ Heavy industry companies (Tier 1s)

- Civil aircraft production value in Japan in June 2021 **decreased by 51% year-on-year basis**.
  (Aircrafts decreased by 60%, Aircraft engines decreased by 44%.)

■ Small and medium-sized suppliers

- **More than 80% of companies** decreased in sales.
- **by 30% or more** year-on-year basis.



Sales of Japanese aircraft SMEs suppliers
(year on year)

Survey of 80 Main SMEs suppliers

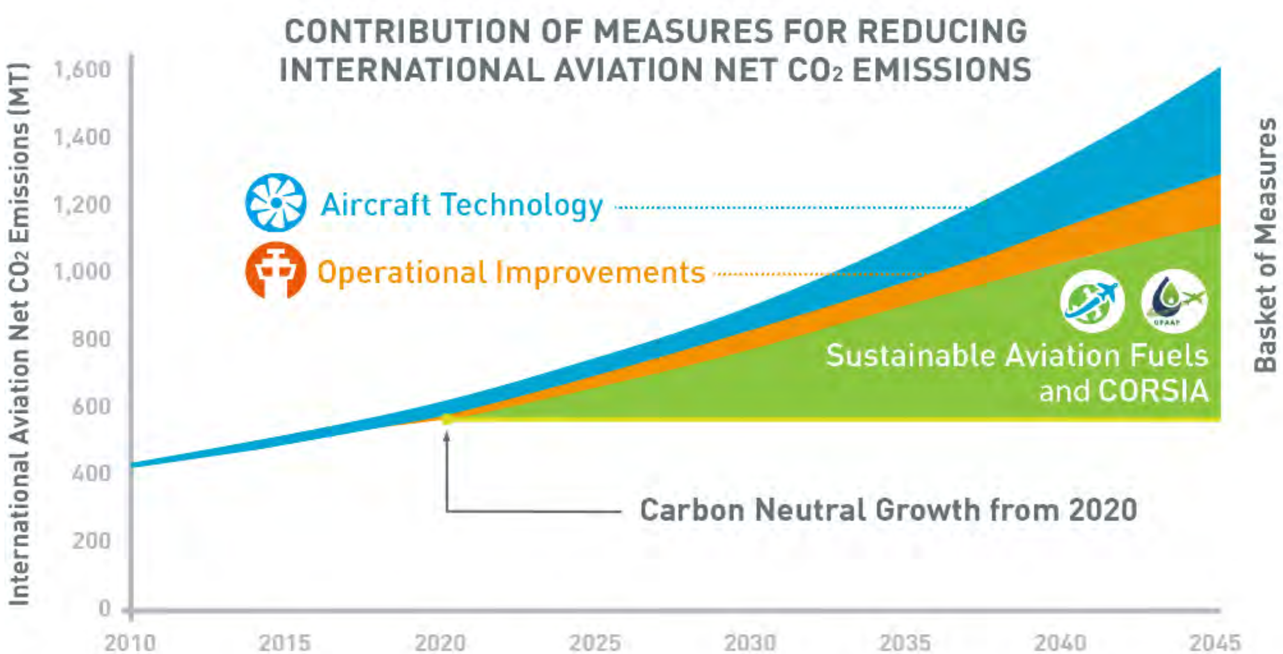
International Goals for CO2 Reduction

- **ICAO**, the international organization for the aviation industry, has **set an aspirational goal of carbon neutral growth** from 2020 onwards; **limit CO2 emissions** by the international aviation sector **after 2021 to 2019 level** (base emissions).

<Image of projected CO2 emissions from international aviation and emission reduction targets>

Means of achieving goals

(1) Introduction of new technology (new aircraft, etc.),
(2) Improvement of flight operation methods,
(3) Use of Sustainable aviation fuels,
(4) Use of market mechanisms



Source: International Civil Aviation Organization (ICAO)

Timeline for Introduction of new technology

- **There is no single option** which is able to achieve the international goals for CO2 reduction.
- Each technology should be developed. We would settle down to develop related technologies, **especially the ones Japan has advantages**, even for long term period.

＜An indicative overview of where energy options could be deployed in commercial aviation＞

	2020	2025	2030	2035	2040	2045	2050
Commuter » 9-19 seats » < 60 minute flights » <1% of industry CO_2	SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF
Regional » 50-100 seats » 30-90 minute flights » ~3% of industry CO_2	SAF	SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF	Electric or Hydrogen fuel cell and/or SAF
Short haul » 100-150 seats » 45-120 minute flights » ~24% of industry CO_2	SAF	SAF	SAF	SAF potentially some Hydrogen	Hydrogen and/or SAF	Hydrogen and/or SAF	Hydrogen and/or SAF
Medium haul » 100-250 seats » 60-150 minute flights » ~43% of industry CO_2	SAF	SAF	SAF	SAF	SAF potentially some Hydrogen	SAF potentially some Hydrogen	SAF potentially some Hydrogen
Long haul » 250+ seats » 150 minute + flights » ~30% of industry CO_2	SAF	SAF	SAF	SAF	SAF	SAF	SAF

Source: WayPoint 2050 2nd edition (ATAG)

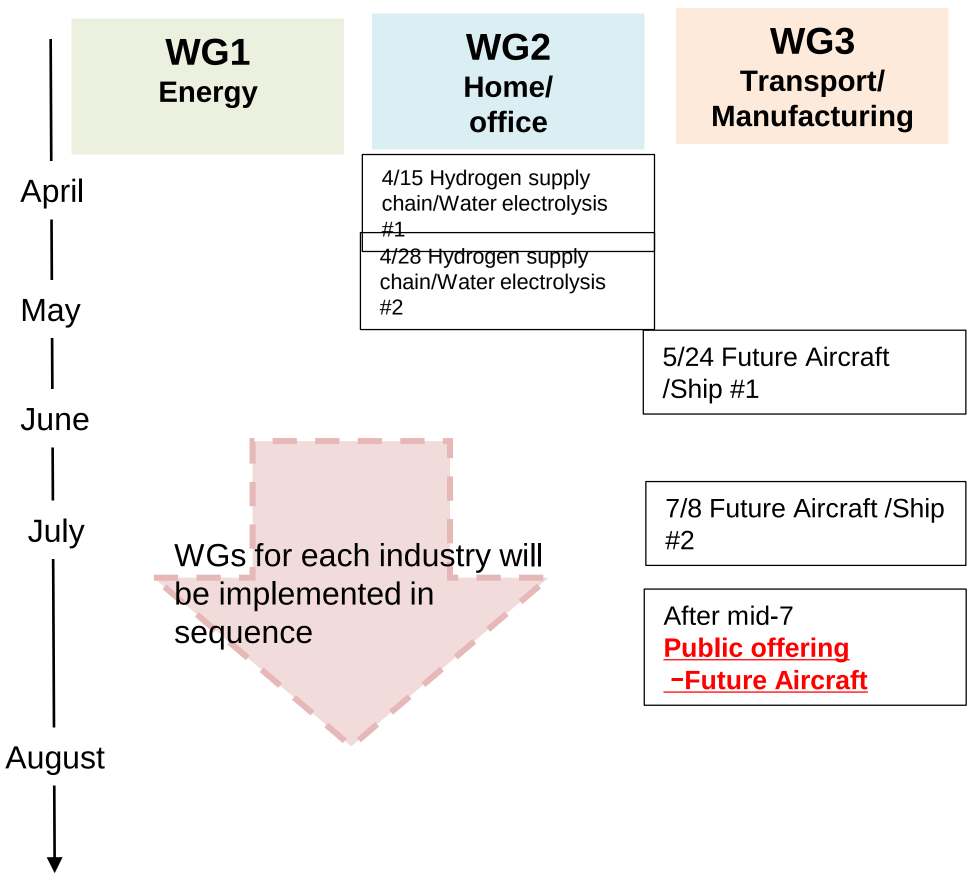
１．航空機産業の歴史

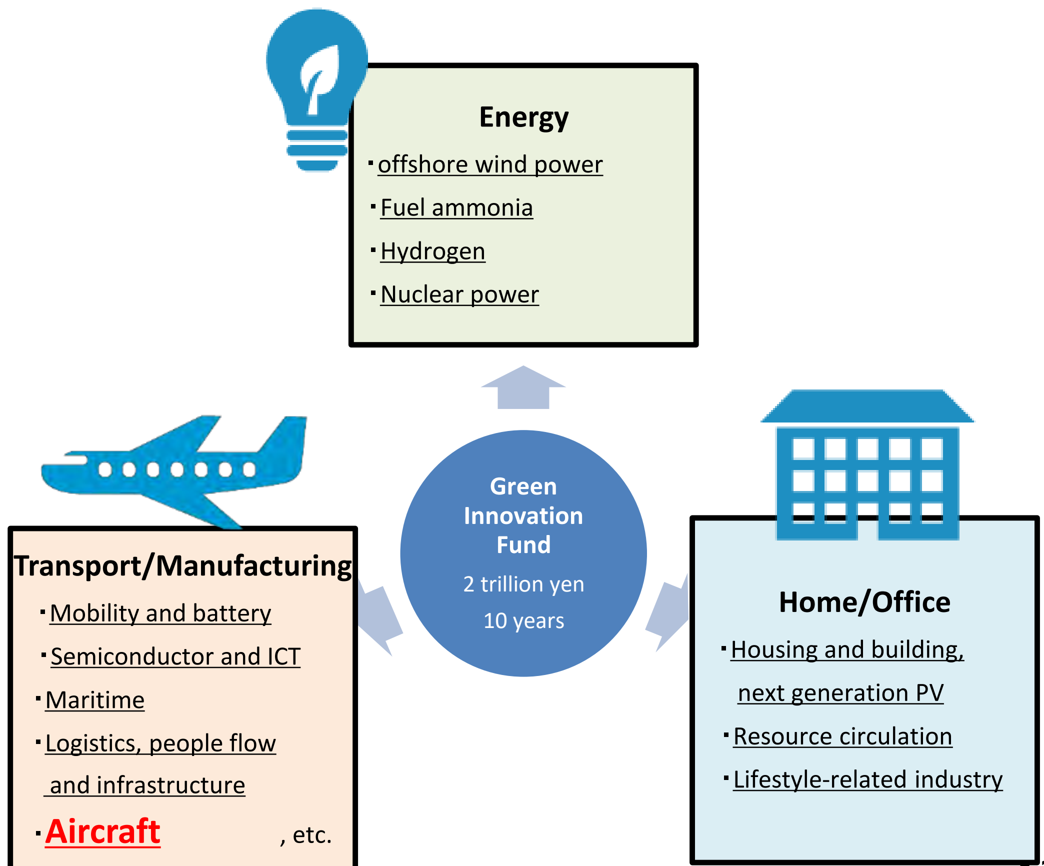
２．世界の航空機産業の潮流（市場成長、環境、各国の施策）

３．今後の方向性、経済産業省の施策
- Future and Related Policies of METI -

Green Innovation Fund of €15,000 million (2 trillion yen)

- METI are going to provide continuing support companies and other organizations for coming ten years, taking up the challenge of ambitious innovations.
- Participating this projects, **companies need to show their commitment to challenge ambitious their business issues ranging from R&D to demonstration to social implementation of the outcomes**.





Goals of the "Next-Generation Aircraft Development" Projects and Details of Their R&D

Total budget:
Maximum of 21.08 billion yen

- As elements necessary for creating a hydrogen aircraft, technical development related to **(1)** an engine combustor that can achieve both stable combustion of hydrogen and low NOx emissions; **(2)** a small, lightweight liquid hydrogen storage tank that can withstand extremely low temperatures (-253°C); and **(3)** airframe design, which will require significant changes **(Goal (1)).**
- Aim to dramatically reduce the weight of the aircraft structure, with a view toward post-next-generation aircraft (post 2035) **(Goal (2)).**

Goal (1)
- Detail (1): Development of engine combustor technology for hydrogen aircraft
- Detail (2): Development of liquid hydrogen fuel storage tank technology
- Detail (3): Considering the structure of hydrogen aircraft airframes

Goal (2)
- Detail (1): Development of technology to dramatically reduce the weight of aircraft's major structural components

Blended Wing Body released by Airbus


Transonic Truss-Braced Wing released by Boeing

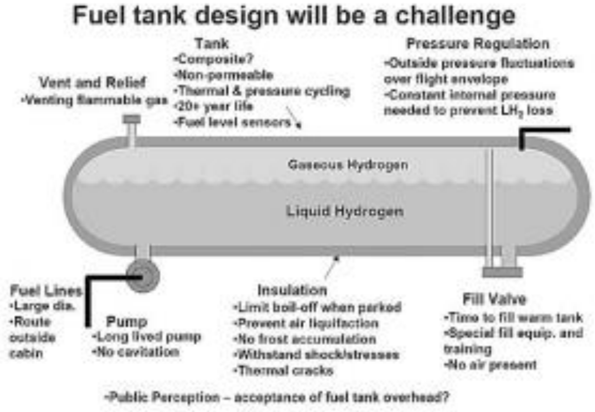
Considering Hydrogen Fuel Storage Tanks and the Airframe Structure

- From the perspective of reducing weight, a practical approach to using hydrogen fuel in aircraft is to store it onboard as a liquid, in which state it will be high in density and low in pressure. Storing liquid hydrogen onboard will require **about four times the volume as for existing fuel**, so the structure of the whole airframe needs to be considered.

- The tanks also need to be made **lightweight, safe, and able to support cryogenic temperatures**. In addition, **a fuel supply system** needs to be developed **to supply hydrogen fuel stably from the storage tank to the engine**.

Hydrogen fuel storage tank

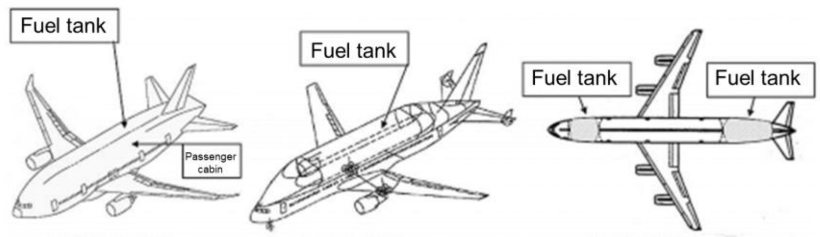
- While liquid hydrogen tanks have been commercialized for rockets, the different requirement characteristics mean that none have been commercialized for aircraft yet.
- For aircraft, they will need to be simultaneously made sufficiently lightweight, durable, and airtight.
- Suitable technologies for fitting in aircraft also need to be developed for the vent pipes, relief valves, pumps, supply valves, etc.



Fuel supply system

- While jet fuel is stored in the main wings, liquid hydrogen occupies about four times the volume. This means the tank placement, etc. needs to undergo a radical review.
- In addition, a supply system needs to be developed to transport the cryogenic hydrogen fuel from the storage tank to the engine.

Example: Considering fuel tank placement



Source: Japan Aerospace Exploration Agency (JAXA), "Current status of R & D on hydrogen fueled aircraft: A review"

Addressing Significant Changes in Aircraft Structure

- Developing hydrogen aircraft for introduction from 2035 onward and airframes that aim to further improve fuel efficiency may require significant changes to the structure of the aircraft. Accommodating these structures will require **significantly increasing the strength of the structural materials**.

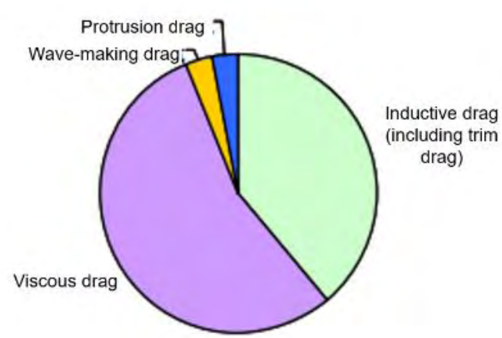
Blended Wing Body released by Airbus

Transonic Truss-Braced Wing released by Boeing

- Although there are issues regarding the feasibility of the airframe form and many other matters, research on the Blended Wing Body (BWB) as a hydrogen fuel airframe is being conducted in various countries.

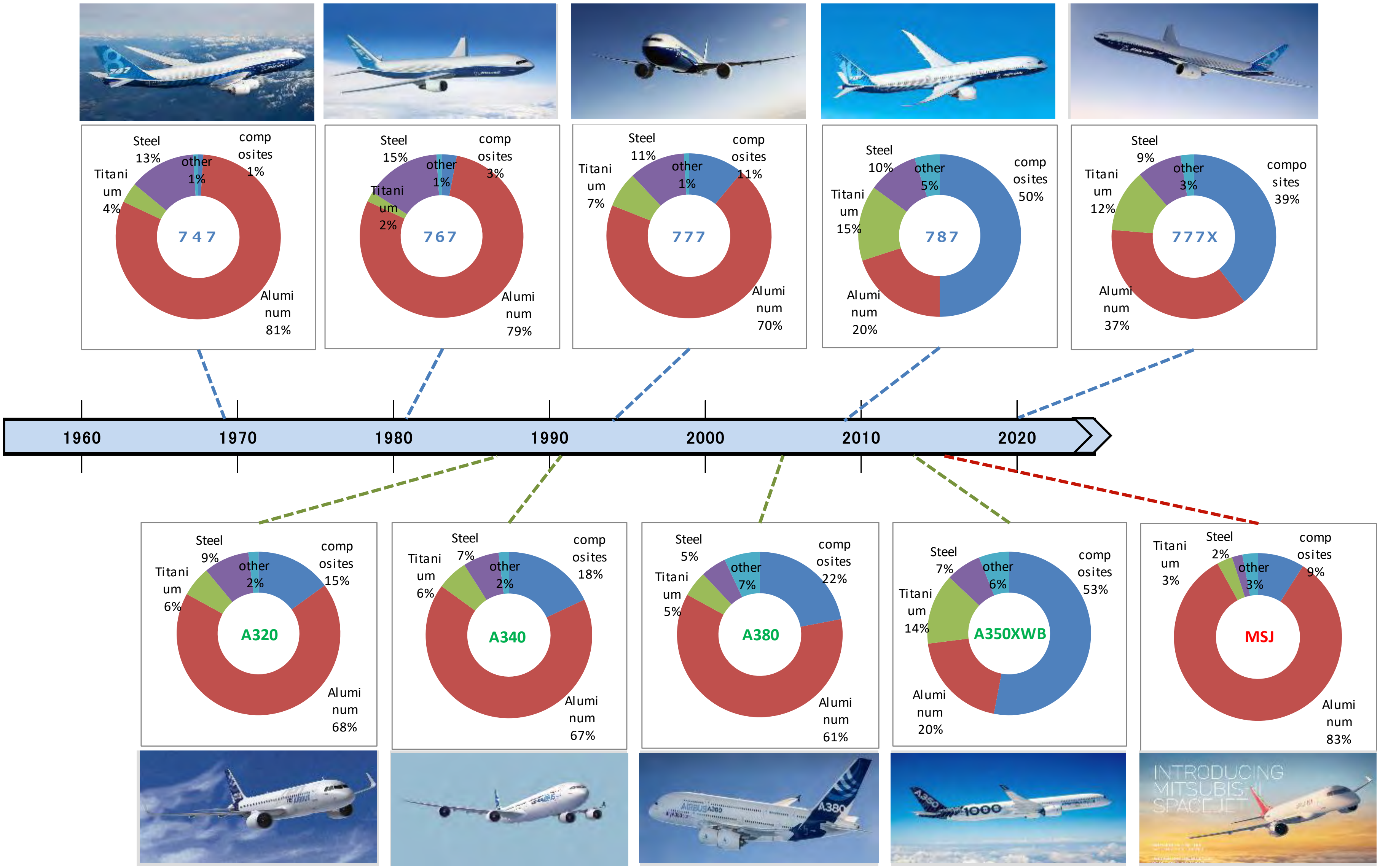
- Viscous drag (surface friction drag, etc.) and inductive drag (drag that arises when lift is generated) make up 90% of a passenger aircraft's aerodynamic drag during cruising, so reducing both of these is an effective approach.

Example: Increasing the aspect ratio of the B787's wings has given it lower aerodynamic drag than conventional aircraft.



Source: International Aircraft Development Fund, "Aerodynamic Technology for Achieving Eco-Friendly Aircraft"

Light-Weighting in Aircraft Body



Technological Development to Improve Strength and Reduce Weight

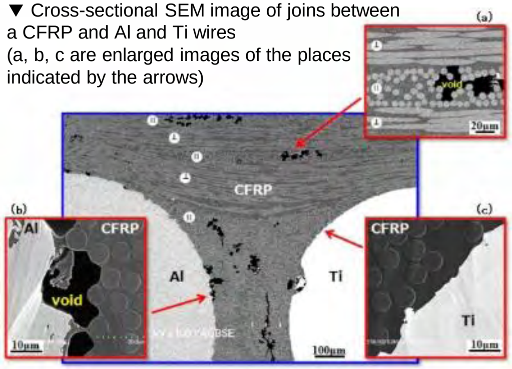
- Accommodating significant changes in the aircraft structure will require **the strength to be improved**. Technology needs to be established to **reduce voids and wrinkles**. In addition, **significantly reducing the weight** will require the number of fasteners in joints to be reduced, while maintaining reliability. An important challenge is to reconcile this technological development with achieving production rates and costs that meet demand.

- The difficulty of predicting the failure of carbon fiber composites is a technical challenge. An important task is to proceed with technological development while also recognizing the importance of guaranteeing the safety of carbon fiber composites, establishing methods for evaluating weight savings, **and establishing non-destructive inspections with a view toward when the aircraft are in operation**.

No voids

- Factors such as air and moisture in the resin can cause voids.
- Voids reduce the strength characteristics of CFRPs, so molding technology needs to be established that will reduce them as much as possible.

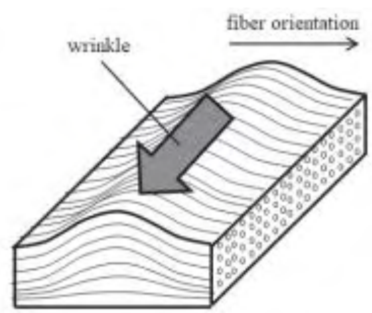
▼ Cross-sectional SEM image of joins between a CFRP and Al and Ti wires
(a, b, c are enlarged images of the places indicated by the arrows)



Source: Nitto Analytical Techno-Center Co., Ltd.'s website

No wrinkles

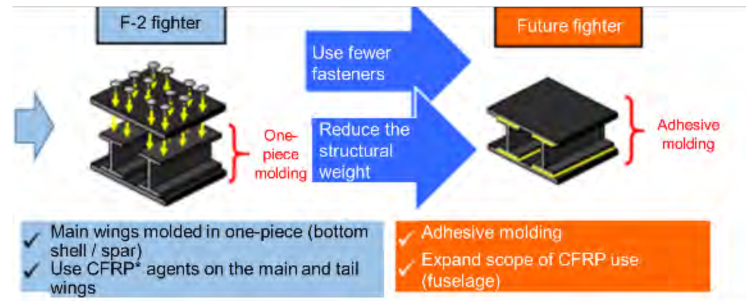
- Wrinkles can occur especially during the process of molding thick CFRPs.
- Wrinkles lead to insufficient rigidity and strength, so molding technology needs to be established that will reduce them as much as possible.



Source: Osaka University, ShinMaywa Industries, Ltd.,
"Study on the limits for wrinkling during molding of carbon fiber-reinforced composites"

No fasteners

- Every fastener (nut or bolt) used in a joint adds to the weight and cost.
- Reducing the weight will require establishing joint technology that does not use fasteners, while maintaining the reliability of the joints.



Source: Acquisition, Technology & Logistics Agency, "Study on technology for lightweight airframe structures: External evaluation report"

Green Growth Strategy
Roadmap (aircraft industry)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/ cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax, [5] budget, [6] finance, [7] public procurement, etc.

	2021	2022	2023	2024	2025	-2030	-2040	-2050

Transport-ation

★Regulation
Regarding international aviation, ICAO institutionalized not to increase CO2 emissions compared to 2019 (2021-2035)

★Goal
CO2 emissions halved from 2005 as of 2050 (IATA target)

● Electrification

- R & D for **equipment electrification** → **Technology demonstration** → **Technology installation and expanded adoption**
- R & D for **electrification of propulsion system (hybrid electric)** → **Technology demonstration** → **Technology installation and expanded adoption**

* Electrification technology can be installed sequentially from small machines (from the latter half of the 2020s)

● Technology development for hydrogen-powered aircraft

- R & D for **core technology for hydrogen-powered aircraft** → **Technology demonstration** → **Technology installation and expanded introduction**

● Weight saving Efficiency

- R & D for **engine efficiency (material, design, etc.)** → **Technology demonstration** → **Technology installation and expanded adoption**
- R & D for **carbon fiber** composite for airframe structure / **Technology demonstration** / **Technology installation and expanded adoption** → **Independent expansion**

* **Engine, electrification, and hydrogen related technologies are partially complementary to one another.**

Strengthen international cooperation with Europe and the United States for the above items

● Jet fuel

- **【Bio jet fuel, etc.】** Establishment of stable fuel manufacturing technology and cost reduction → **Expanding supply** of competitive bio-jet fuel, etc. in response to **trends in the international market for bio-jet fuel, etc.**
- **【Synthetic fuel】** Establishment of integrated manufacturing process from CO2 to synthetic fuel

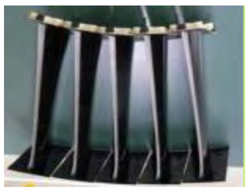
* For bio-jet fuel by culturing microalgae, refer to the implementation plan of the carbon recycling industry.

Changes of the Materials and Technologies of Aircraft Engines
- Efficient thermal management, Light-weighting-

炭素繊維複合材（CFRP）部品

- ◆ 軽量（アルミ合金の約2/3の比重）
- ◆ 高耐衝撃性

ファンケース

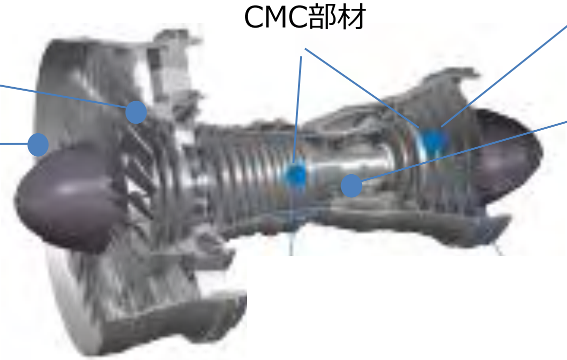


構造案内翼

CMC部品

- ◆ 軽量（ニッケル合金の1/4の比重）
- ◆ 耐熱温度1300℃以上

CMC部材



次世代合金

<チタンアルミタービン翼>

- ◆ 軽量（ニッケル合金の1/2の比重）

<次世代ニッケル合金タービンディスク>

- ◆ 高温・高強度鍛造素材

鍛造用プレス機
（参考：日本エアロフォージ）

高速切削技術

- ◆ 5軸MC等の導入による高生産性・低コスト

接合技術

- ◆ LFW（線形摩擦接合）等による低コスト組立（素材費削減）

粉末成型技術

- ◆ 金属粉末射出成形（MIM）や三次元積層造形（AM）による一体成形、低コスト化（素材費削減）

（出展）内閣府SIP「革新的構造材料」パンフレット他

The Future Manufacturing in Aviation Industry

Example of Automation（Riveting）

Conventional manufacturing method :
Boeing 777

New manufacturing method :
Boeing 777X

Insights from Boeing CEO（@ quarterly earnings call on 28 Apr., 2021）

Extractions from the article of "Flight Global", 29 April 2021

Boeing chief executive David Calhoun believes that the next generation of aircraft will distinguish themselves by the way they are engineered and constructed, rather than through increasingly efficient engines alone.

*… "**I expect the next product will get differentiated in a significant way on the basis of the way it's engineered and built**," Calhoun says. …*

Agreement between METI and Boeing on Cooperation in Aircraft Technology

January 15, 2019

State Minister Isozaki, METI
Chief Technology Officer Hyslop, The Boeing Company

Meeting with Boeing on cooperation in future technologies based on the agreement

<focus areas>

○electric technology, including advanced lightweight batteries and advanced motors and controllers necessary for electric propulsion systems in aircraft

○high-rate low-cost composite production technologies

○advances in automation to improve manufacturing productivity.