【孫子 – AM】
MM1　Feb12
対象市場：②

# 「輸送系 主要対象市場 焦点分野」
# 【特3B：企業研究シリーズ
# Boeing社 の未来】

## 航空 AM (Additive Manufacturing)
## 2021年以降の対応

尼子 清夫

代表取締役　MacA M1 株式会社　　URL：macam1.com

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2021年 2月12日

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- 「Boeing社 ものづくりの未来 2019年 ~」 (2/ 6/ 2019 at 幕張メッセ)
  **Brett C. Gerry**, President, Boeing Japan

- 「Trends in Aerospace Manufacturing」
  MECT 2017 (0ct 2017) and CIM 2016 (0ct 2016)
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- Boeing AM News (2016年10月 ~ 2020年12月末)

- Boeing vs Airbus

# Boeing社 新たな挑戦 2021年 ~ (1/3)

## 「New Horizons – 航空機産業の発展

President, Boeing Japan (acting V.P. Boeing International)

<Former GM, Sikorsky Aircraft Corp., United Technologies Corp.>

William Shaffer (2 / 3/2021 at "AEROTECH TOKYO")

● **Focus Area in Collaboration 提携の注力ポイント** (1/2)

with Japanese Government and/or Tier 1s

- ＊ **METI** Technical Collaboration Agreement 2019
- ＊ **JAXA** LIDAR CAT 2018
- ＊ **Toray** CFRP LTA B777X & B787 2014
- ＊ **JADC** LTA B777 / 777X, B767 & B787 2013

**< Future Technologies to focus on applications on completion of R & D >**

- ✓ Operability 運用性 : "Cabin Air Purification (Protection from a Virus)"
- ✓ Sustainability 持続性 : ① Hydrogen、② Aviation Fuel
- ✓ Producibillity 生産性 : **AM 応用が第一、CFRP (20% Efficiency)**

# Boeing社 新たな挑戦 2021年 ~ (2/3)

## ● Focus Area in Collaboration (2/2)

< Future Technologies to focus on applications on completion of R & D >

* **MBE** (Model Based Engineering) :
  "Model Based Exchange & Digital Thread" ☛ **AM**
* **APQP** (Advanced Product Quality Planning) : "Process Control" ☛ **AM**
* Full Size Determinant Assembly
* Safety Management System

**Boeing Defense Platforms**

Reduced Cost & Schedule ⇔ Design &
Manufacturing Tools and Processes

# Boeing社 新たな挑戦 2021年 ~ (3/3)

## ● Aerospace Business Environment 事業環境

### ◆ Commercial Market Trends

＊Passengers - 2019年 vs Dec. 2020 North America 56%, China 64%,
EU 24% (World 48%)

2018年 Actual Traffic RPKs : 8 Trillions ☛ 2020年 2T ☛ 2024年 10T

＊Near Term Demand Supply & Regulation

Governments : Sustainability / Travel Regulation / Infrastructure

Airlines : Fleet Decisions / Workforce / Capital

＊Market Resilience 回復力 ☛ Market Diversity / Emerging Markets / Innovation

Versatility 汎用性 ☛ Capability / Network Flexibility

＊Single-Aisle 機 (B737 & A320 其の後継機種)

☛ 2020~2029 : 18,350 新機 (13,570 旅客機) 全65%

2020~2039 : 43,110 新機 (32,270 旅客機) Asian & China Fleet 30~40%

### ◆ Protection from a Virus – 今後注力・必須のエンジニアリング

＊In-flight – "Clean Air - HEPA" / Cabin Airflow (UV Study)

UV built into the airplane

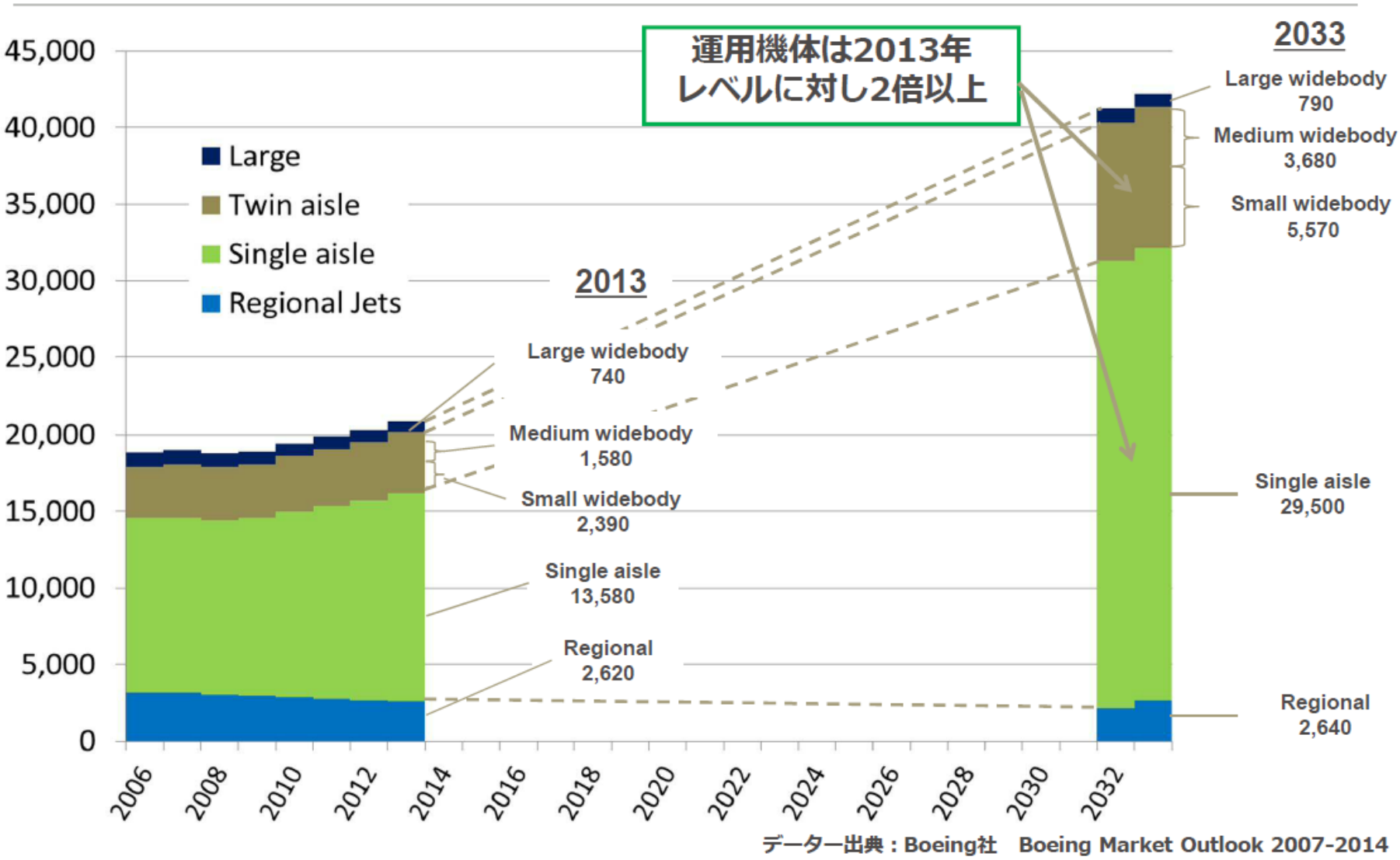
anti-virus coating / Inonization Technologies

「How does cabin air compare to everyday life ?」

☛ Uniform Testing and Screening Protocols, Critical International Travel

空気洗浄に貢献する AM ?

# <参考> Boeing社 民間航空機需要予測 (2014)



# Boeing社 ものづくりの未来 2019年 ~ (1/3)

## 製造の未来 President, Boeing Japan Brett C. Gerry

(2 / 6/2019 at Aerospace R & D Exhibition in Makuhari)

- **Digital 化の方向** IoT / AI / Data Analytics

  * **VR 仮想現実** – Harnessing Virtual

  * **Composite 複合材** – Composite Fabrication

  * **AM** – Additive Manufacturing ⇒ 777X Wing Tool (2020 ~)

  * **Robotics & Automation** – ロボット活用・自動化

    737 Factory (1999 ~) ⇒ “繰り返し改善“ 737 Max / Moving Line (2018 ~)

# Boeing社 ものづくりの未来 2019年 ~ (2/3)

## Boeing社 が示す 新たなトレンド 「航空機電動化」

プレイヤー (プロジェクト名)

### 旅客機 (１００人乗り以上)



- 2030年代までは「装備品」（油圧アクチュエータ等）の電動化技術適用
- 小型航空機での技術実証・評価を通した「推進系」の電動化に期待

### Regional/Business Aircraft (１００人未満)



- E-fan X による革新電機技術の実証（２MW級の電動モーター技術実証を2020年）や Zunum Aeroによる商用化（6-12席は2022年、50-60席は2027年）

### EVTOL/Flying Car (1人-5人)





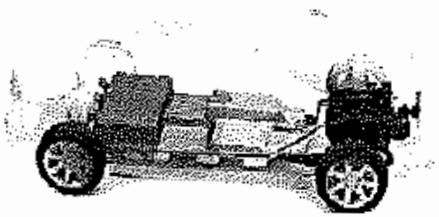

- 開発競争加速（世界で50以上のプロジェクトローンチ）
- 既存技術での早期実現（2020年代前半）

1

# Boeing社 ものづくりの未来 2019年 ~ (3/3)

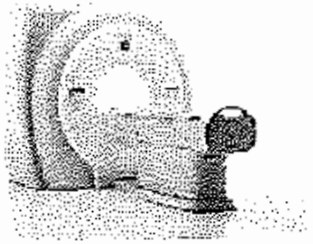
## Boeing社 が示す電動化技術 – 日本への期待

### バッテリー関連技術



✓ LIB特許出願シェアランキング1位
※日本52.7%,韓国17.7%(2006-2010)
✓ 革新的蓄電池の研究開発実施（NEDOプロ）

### モーター関連技術

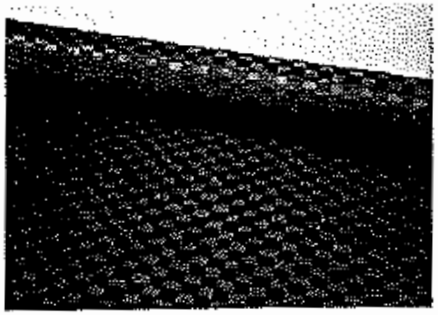


✓ 産業用モータのシェア上位10社のうち5社が日本
※GOULDEN REPORTS (グールデン・レポーツ) / February 2014
✓ 超電導モータの線材技術等にも期待

### インバーター関連技術

✓ パワー半導体の特許出願シェアランキング１位
※日本(49.0%)、米国（25.2%） (2003-2012)

### 機体部材関連技術



✓ 炭素繊維複合材の航空機への適用（B787）

# E N D

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# Trends in Aerospace Manufacturing

**Lane Ballard, V.P. Materials & Manufacturing Technologies**

**The Boeing Company**

**MECT 2017 (0ct 2017) and CIM 2016 (0ct 2016)**

**October 23, 2017 Memo, written by Kiyoo (Mac) Amako**

**Lane Ballard : MIT Master Degree, 1982**

**Boeing 1982 ～ Lean Manufacturing, Quality Management,**

**(Present) New Materials (CFRP & Ceramic, Metals)**

# Presentation Contents (Oct 2017)

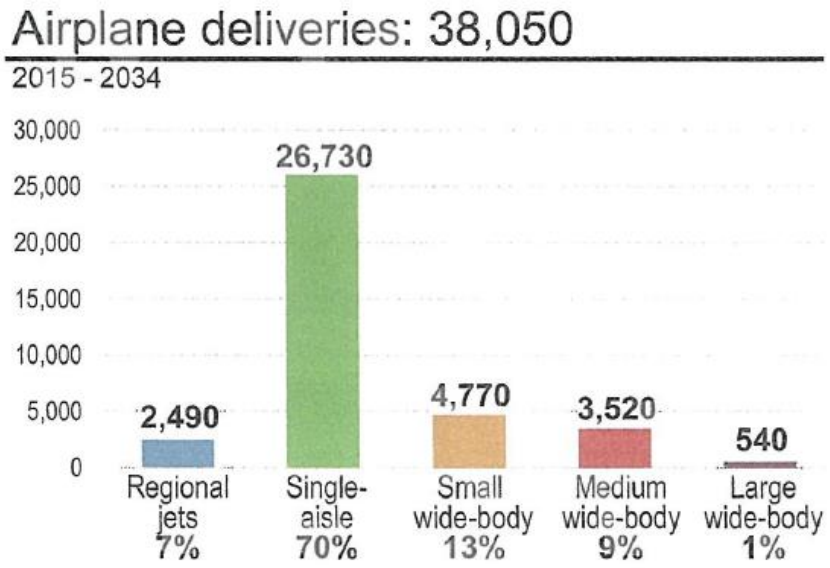
1. Launching our 2nd Century (with DVD: Boeing's 100 Year Anniversary)
   - A company and history like no other
   - Boeing: the World's Aerospace Innovation Leader
   - Boeing in Japan
   - Airlines will need : 40K new airplanes by 2035
2. Beyond the 1st Century of Aerospace Manufacturing
3. Industry Realities
4. Market Challenges
5. Challenges & Opportunities Ahead
6. Aerospace & Automotive Comparison
   - Engineering – Digital Definition
   - Advanced Materials
   - Expanding Capability for utilized machine components
   - AM (Additive Manufacturing) Innovation
   - Titanium Additive / Subtractive Innovation
   - Automation Innovation
   - Manufacturing Analytics & Digital Threads
7. Summary

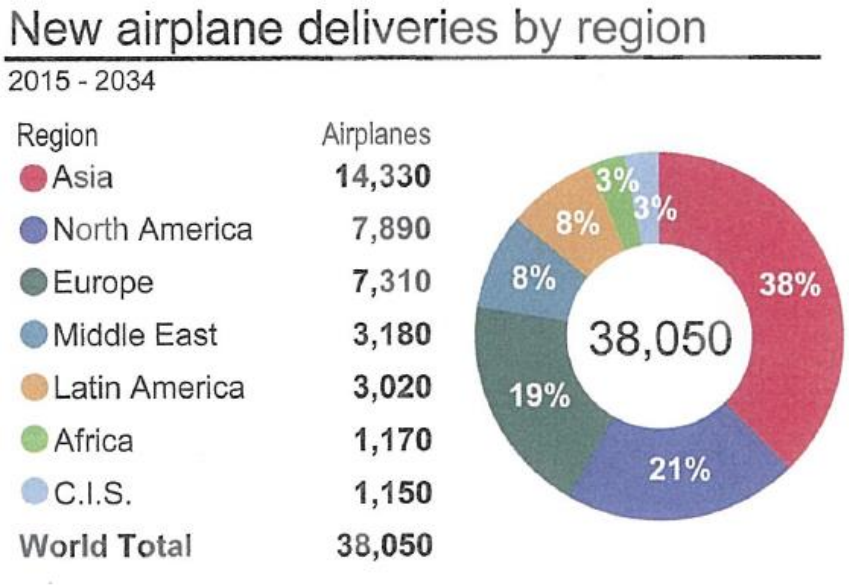
An Era of Accelerated Disruption (New Partners / Investment)

DVD – B787 Dream Liner & B737 Max in Flight

# 1. Launching our 2nd Century

- A company and history like no other
- Boeing : the World's Aerospace Innovation Leader
  - $ 94.6 B sales / 145K employees / 20K ~ suppliers / 65 countries
- Boeing in Japan (by the numbers)
  - 80% commercial market share (970 airplanes / 94 B787s)
  - 300 defense aircrafts
  - 200 team mates / 7 universities / $ 5B procurement



# 2. Beyond the 1st Century of Aerospace Manufacturing

**Automated Composite Lab**

**AM (Additive Manufacturing) = Paradigm Shift**

**Robotic Assembly**

# 3. Industry Realities

## - Industry customers are demanding more for less

- May 2015
  Doubts plague aerospace industry ahead of Farnborough Airshow
- June 2015
  Boeing & Airbus face mammoth task to clear order backlog
- March 2016
  Honeywell cuts 2016 sales forecast on weak aerospace demand
- July 2016
  Production cut drives deeper loss at ATI
- July 2016
  GKN to cut jobs and reduced investment
- Sept. 2016
  Rise in aircraft demand forces supply chain to modernize
- Oct. 2016
  Should – cost Review to improve Affordability ?
  The US DOD is experiencing unprecedented cost pressures as demands to reduce government spending rise.

# 4. Market Challenges – What the customers want

- Safe
- Affordable
- Reliable
- Upgradeable
- Flexible
- Performance
- Environmentally Responsible
- Available

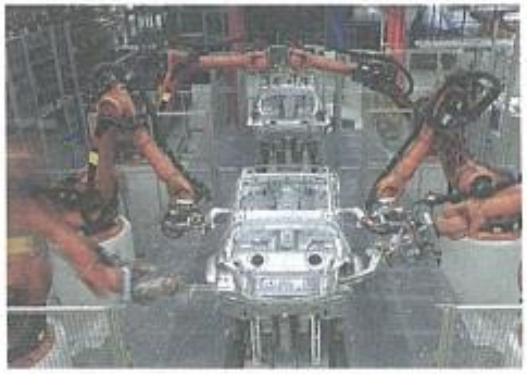
B787 : 20% or more Savings of Fuel Consumption

Year 2020 ~ : Significantly Improvement of Manufacturing Efficiency

⏭ needs to speed-up

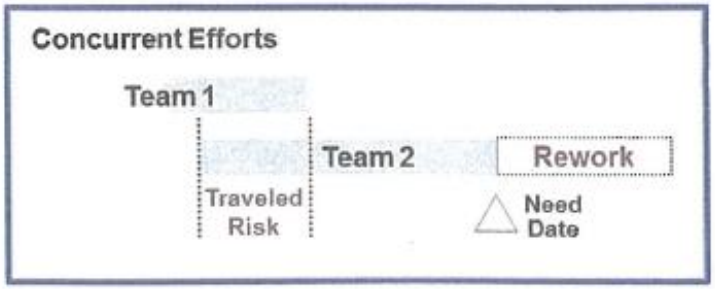
# 5. Challenges & Opportunities Ahead

- **Design for Manufacturing**
  「最適設計が解決の第一」
  “より多く、より早く作る”



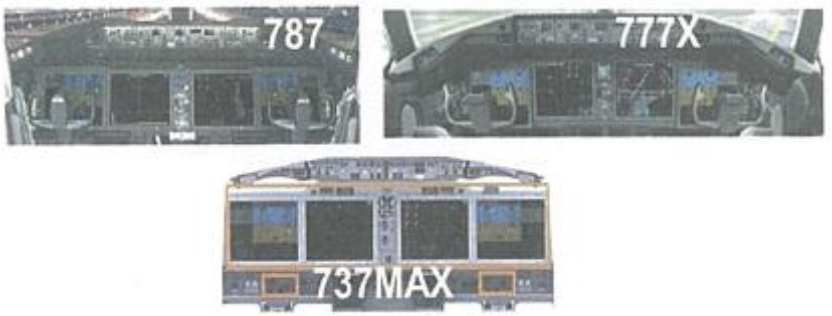
航空機製造
に特化した
自動化技術

- **Traveled Risk「リスク制御」**
  “手戻り”－工程間の同期性の高まり




- **Speed to Market「AMが最大の威力」**
  “市場投入までの納期短縮”

- **Modularity「ﾓｼﾞｭﾗｰ 設計」**
  “顧客毎のｶｽﾀﾏｲｽﾞ及び
  機体ｼﾘｰｽﾞ間共通部品“



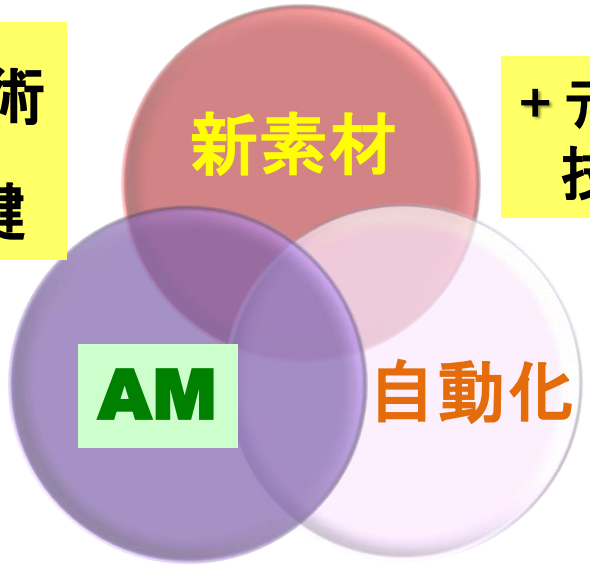
# 6. Aerospace & Automotive Comparison
## 6-1. Engineering – Digital Definition

| | < 航空 > B787 | vs | < 自動車 > BMW I3 |
|---|---|---|---|
| ・部品点数 | 2.3M / 機体 | | 10K / 台 |
| ・生産量 | 12 / 月 | | 2,100 / 月 |
| ・総計部品点数 | 27 M / 月 | | 21M / 月 |

2002年以降 Boeing社は
50,000 個超える部品を
AMで製作

迅速に、高品質な航空機を製造

製造技術
3ヶの鍵



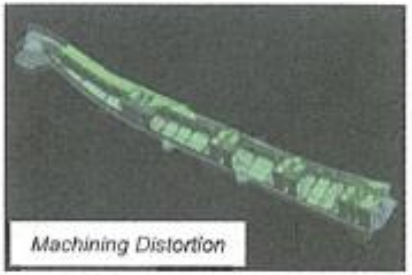

＋ﾃﾞｼﾞﾀﾙ
技術応用

素材加工 (切削) =『引き算技術』
AM
新形状・新設計 =『足し算技術』

# 6-2. Advanced Materials

## - Product Performance & Production System Efficiency

- **Top Business Outcomes**
  - Safe / Environmental / Ergonomic Processes
  - Robust First Pass Quality
  - High Rate Capability
  - Reduced Part Count
  - Optimized Weight and Cost
- **Top Advanced Materials Applications**
  - Metallic Alloys
  - Composites
  - Sealants / Paints
  - Ceramics
- **Enablers**
  - High Rate Processes
  - Integrated Materials Modeling, Fabrication Processing and Properties




Computational Materials Models

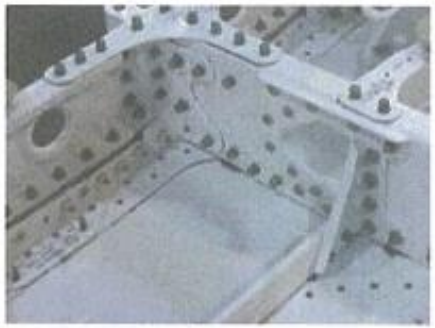
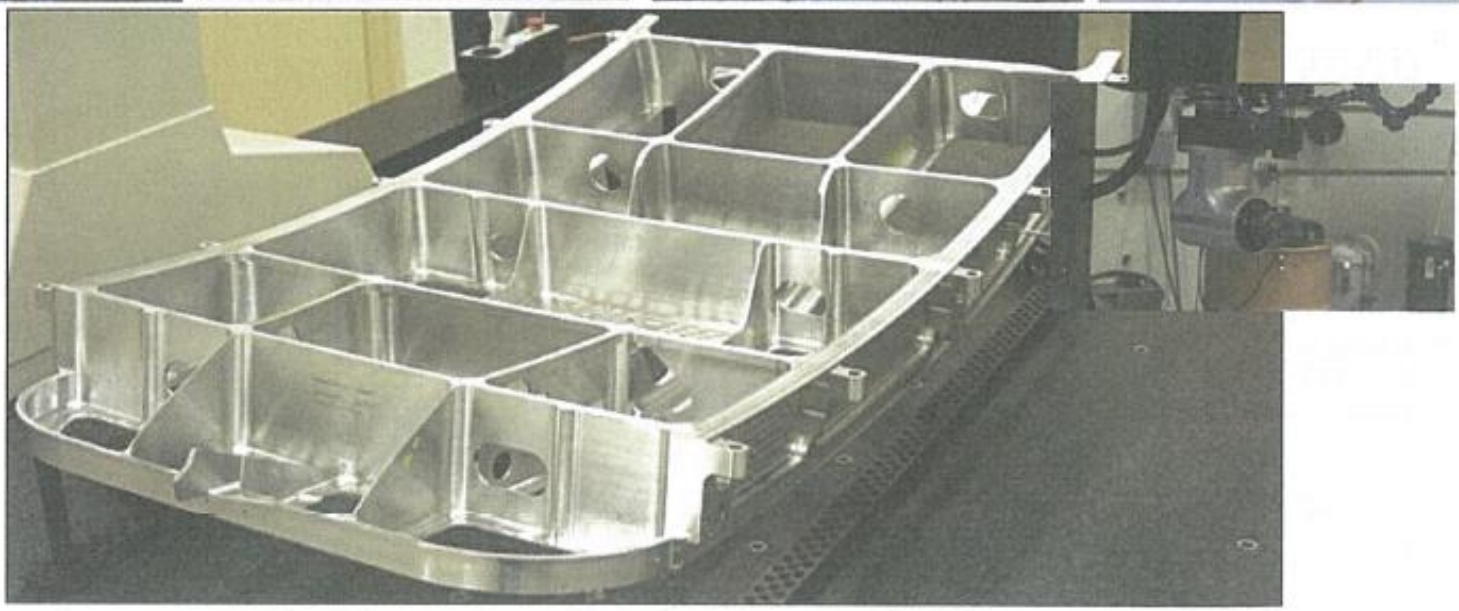

Reduced Part Count


Robust Seal / Paint


Materials for Extreme Environments (Ceramics)

# 6-3. Expanding Capability for utilized machined composites - Advanced modeling / machining technology critical



**B787 : Very Important for advanced modeling / machining technologies to be combined**

⏭ **Boeing Strategy for AM Exploitation**

# 6-4. AM Innovation
## - Since 2002 more than 50K flyaway parts!

- 注目効果
  - Speed to Market
    (市場投入までの時間)
  - 性能飛躍的向上
  - コスト 低減 (Buy-to-Fly、
    製品本体に占める原材料)
  - 柔軟な製造
- 顕著な適用事例
  - ﾌﾟﾛﾄﾀｲﾋﾟﾝｸﾞ
  - 治工具
  - 機能部品
  - 構造部材
- 効果的手段
  - 認証
  - 製造工程間検査

仕上げ・型押し　　金属系　　ポリマー系

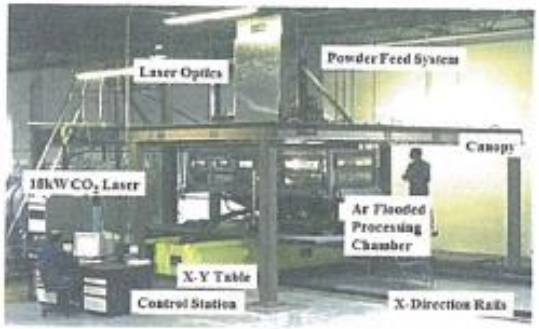
仕上げ : B777X, 主翼 Trim & Drill Tool – Oak Ridge National Lab

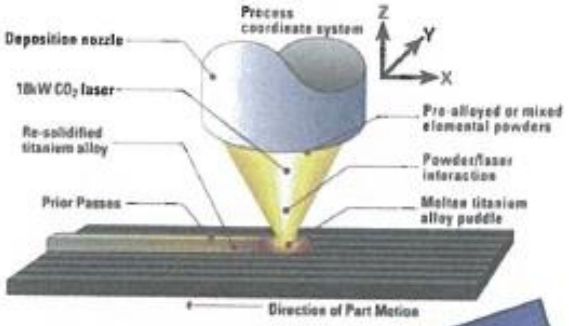
内装 : JAL, ﾎﾟﾘﾏｰ / 表面仕上げ

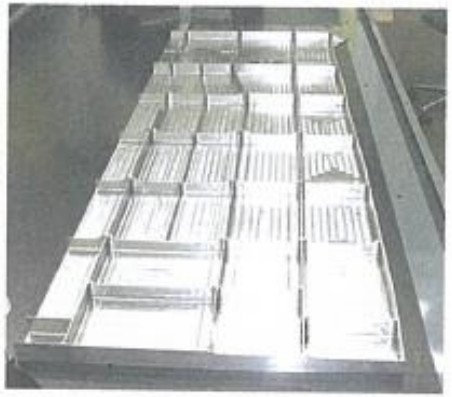
飛行搭載部品 : 主要な製造工程品質管理, 特殊材料 (金属系 & ﾎﾟﾘﾏｰ系)

# 6-5. Titanium Additive / Subtractive Innovation

## - Complex to complex machining will continue to grow!



# 6-6. Automation Innovation
## - Innovative, Simple, Robust & Cost Effective

- **Top Business Outcomes**
  - Workplace Safety
  - Product and Process Quality
  - Flexibility & Factory Optimization
  - Standardization / Replication

- **Top Automation Applications**
  - Drill / Fill
  - Paint and Seal
  - Composite Fabrication
  - Material Movement

- **Enablers**
  - Networked Enabled Manufacturing
  - In-Process Inspection
  - TRL and MRL

B777
Fuselage Flex Tracks

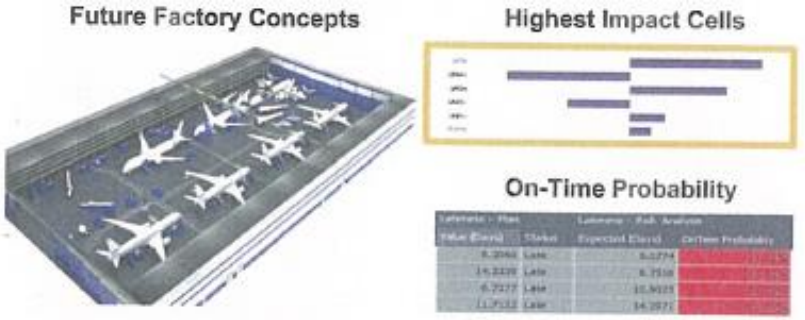
B737 / 787
Heat Shield Line

B787
Aft Robotic Drill / Fill

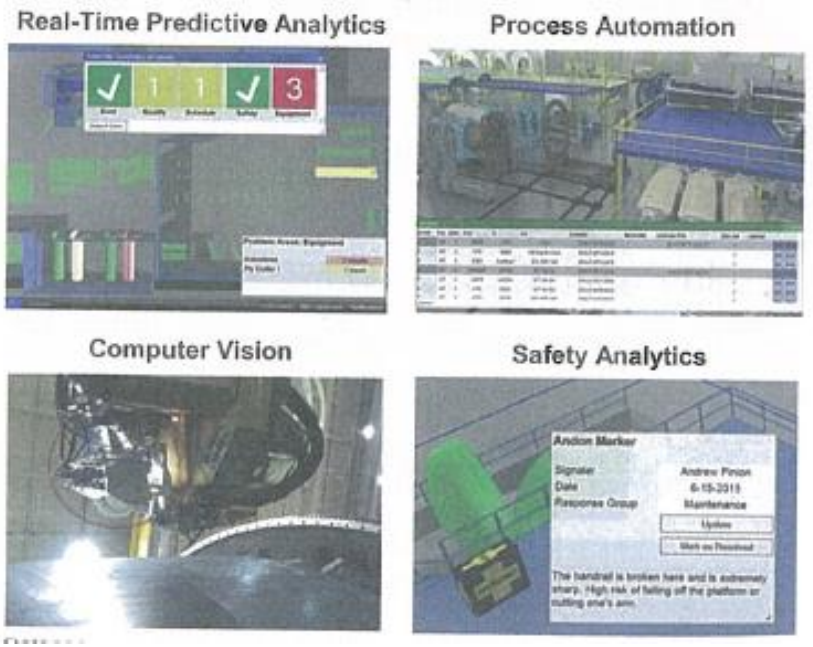
# 6-7. Manufacturing Analytics & Digital Threads

- **Top Business Outcomes**
  - Reduce Test & Evaluation / Rework 50%
  - Affordable Manufacturing
  - First Pass Quality
  - Improved Factory Safety
- **Top Applications**
  - Optimized Factory Flow
  - Manufacturing Process Analytics
  - Improved Automation Execution
  - Robust Process & Material Specs
- **Enablers**
  - Analytics
  - Advanced Modeling & Simulation
  - Industry Standards
  - Integrated Digital Factory

Production Simulation




Integrated Digital Factory
The Complete Picture




Touch Labor Task Guidance User Study : VR (Virtual Reality)
Number of Errors – Dramatically Reduced (90% less)
Tablet AR / Quality +90% / Time to Assemble less 30%

# 7. Summary

- Market challenges and industry realities are driving changes in the way the aerospace industry designs and builds products
  - Cost
  - Speed to Market
  - Performance
  - Environment

- Advances in materials, automation, additive / subtractive manufacturing and data analytics are leading the changes for the 2nd century of the aerospace industry

**An Era of Accelerated Disruption** (New Partners / Investment)

- Horizon X – Entrepreneuership Enterprize in Boeing
- Sparkcognition – **AI** Investment
- Other Flight Sciences

# Boeing AM News (1/5)　2021年 6月末現在（2016年10月以降）

<注1> Boeing 社が公表している AM に関する記事
(Boeing 以外のAerospace Tier 1s に関するものは記載されていない)
☚『AM 事業「航空･宇宙 (民樹･防衛)」における 2016年10月以降の動向』（特3C　MM1　準備中）を参照。

<注2> 2019年初頭 ~ 2020年末の間、Boeing 社 の主要な記事は “737 Max” の飛行再認証 及び “Corona禍経営影響” に関する事項であった。

- Oct. 30, 2020
- **Boeing** は、**Stratasys** **PEKK** (Poly-ether-ketone-ketone) ﾍﾞｰｽ **AM** 材料 (最新の熱可塑剤) を2年間の認定ﾌﾟﾛｾｽ を経て承認。

**従来 3DP では対応できなかった分野に対応**

# Boeing AM News (2/5)

- July 16, 2020
  - **Boeing**：**F-15EX** における「機首バレル、Wings、全部胴体等構造部分の設計図を完全に 3D Digital に置換えており、交換部品が On-demand にて CNC機械加工や **3DP が可能**になり、補用部品調達の迅速化と Maintenance コスト削減に寄与する。」 (F-15EX 運用コスト: US$ 29K / Hr < 44k/Hr by F-35)

- March 30, 2020
  - **Boeing** は、**米国内に所有する 3DP Capability を活用**し、**COVID-19** に対応する為 “Face Shield” を製造することになったと、発表した。

- Oct. 10, 2019
  - **Boeing** & **Thermwood Corporation** は、**AM** technology を用いて B777X 用の大型一体化 Tool を製造したと、発表した。

    **Thermwood** 社製のLarge scale **AM** (**LSAM**) machine と新たに開発した Vertical Layer Print (**VLP**) **3DP** technology を利用して、20% CFR ABSにて 12ft長さの Tool を航空宇宙産業向けの品質に適合して製造することに成功した。

    **Boeing** は **LSAM** & **VLP** をInterior Responsibility Center facility として購入した。

- Aug. 7, 2018
  - **Boeing**：**Digital Alloy 社 (Burlington, USA) に資本投下**
    - Digital Alloy：航空業界に **3DP** 部品を供給 – High-speed, multi-metal AM systems を独自開発、Joint PrintingTM Technology を有し、Tiをはじめとする High-Temperate alloy を活用

# Boeing AM News (3/5)

- June 26, 2018 (1/2)

**【Boeing expects 3DP to help airlines customize cabin interiors】**

1) Boeing currently has AM capabilities at 20 sites worldwide, including at its Salt Lake City, Utah facility, where it makes **3D-printed composite parts** such as footrests and air ducts for the **777X** flight deck.

2) Boeing last month signed a memorandum of understanding with **Israeli software company Assembrix**, which the manufacturer says will enable it to transmit additive manufacturing design information more securely.

"Boeing's collaboration with **Assembrix** will help us expand our cybersecurity digital thread (Assemblix's cloud-based platform) to ensure the appropriate measures are in place to help safeguard the company's IP," says **Kim Smith**, vice-president and general manager at Boeing Commercial Airplanes Fabrication, and Boeing's leader on **AM**.

"An example of that is our collaboration with **Norsk**, which is using a Boeing design and its titanium 3D printing technology to build an interior galley bracket for the 787."

3) **BCA** (Boeing Commercial Airplanes') **Interiors Responsibility Center** in Everett, Washington currently produces **180** AM parts, including cabin interior components. More than **60,000 3DP** parts are already flying across Boeing's commercial, space and defense product ranges.

# Boeing AM News (4/5)

- June 26, 2018 (2/2)

**【Boeing expects 3DP to help airlines customize cabin interiors】**

4) Structural **3DP titanium** part used to hold the **Auxiliary Power Unit door** open for maintenance access when the airplane is on the ground. This part is lighter and easier to install than its traditionally manufactured counterpart.

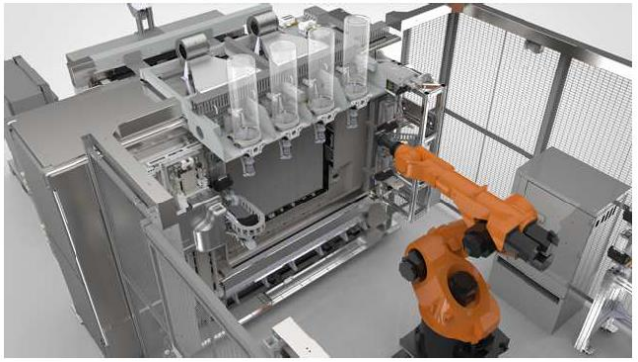
5) Structural 3DP **titanium** aft galley fitting designed by **Boeing** and manufactured by **Norsk Titanium**. This part became the world's first structural titanium **3DP** part installed on a commercial airplane in 2017

# Boeing AM News (5/5)

- April 23, 2018
  AM Specialist である **Morf3D 社** (本拠地：El Segundo, CA, USA) に資本投入
  **Morf3D 社**：2015年後半に設立、Boeing 向け Satellite 部品やHelicopter 部品の 3DP Ti & Al Components の製造実績あり
  → 今後両社は、共同で Aerospace向け AM Standard Process 開発を行う

- Feb. 20
  **Boeing & Oerlikon**：Metal base AM 用 Standard material & Process 開発のため 5年間の業務提携に合意、調印
  両社は、安全で信頼性が高く、コスト効率の良い Structural Titanium Aircraft Component を開発するため Powder Management → 最終製品の製造に至るまでの総合的 AM工程の標準化を共同で実施
  現状：**50K点近い 3DP Parts** がCommercial Aircraft & Space and Defense Program に使用されている

- Oct. 5, 2016
  **Boeing (Research & Technology)**：
  **Stratasys** とMOU締結 (新3DP 共同開発)
  Long Fuselage Tube (101 cm x 76.2 cm)
  – 長尺用Thermoplastic Composite 積層
  – Carbonfiber のThermoplastic Resin 積層



# Boeing vs Airbus