



## Creating Market Pull for Thermoplastic Composites in Defense and Commercial Aerospace

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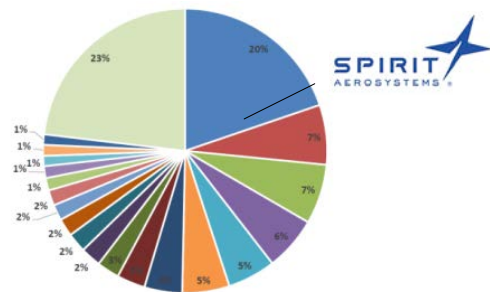
Andi Meyer, Research and Technology

March 23, 2022



# Spirit Is the Leading Global Aerostructures Tier 1 Supplier

Global aerostructures leader



Source: Counterpoint

With a balanced aerostructures portfolio



Fuselage  
(52%)

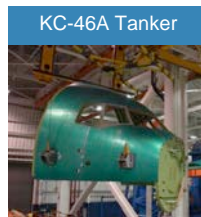
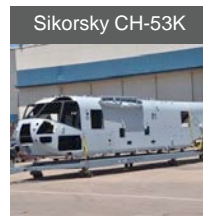


Propulsion  
(26%)

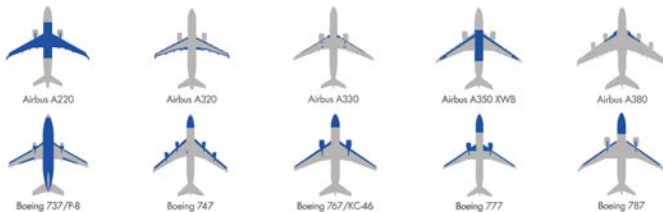


Wing  
(21%)

And an emerging presence in Defense



On all of 12,500 Boeing/Airbus backlog



SPR backlog = \$47.9B



# Why Thermoplastics\*?



*\*Advanced Thermoplastic Composites*

Joby TOYOTA

## Advantages of Thermoplastic Composites

The **re-processability** of thermoplastics opens up new manufacturing options to **reduce flow time, cost, and weight**

- Weldable
- Recyclable
- Automated processes
- No freezers, autoclaves
- Reduced weight
  - Lowers fuel costs
  - Reduces emissions
  - Extends range



*Focus on high volume, high rate parts*  
Joby TOYOTA

## Thermoplastic Composite Challenges



- Up-front, non-recurring costs. Not compatible with existing manufacturing shop equipment

**Developing new design guidelines**

**Scale-up** to longer, larger and more complex parts and assemblies

**Material cost** must be countered by reduced labor

**Certification steps** for many new processes

# Development Activities

- Large, complex parts
  - Scale up stamp forming
  - High-rate AFP + secondary consolidation
  - In-situ AFP
- Advanced capabilities for integrated structures
  - Large, complex welded assemblies



Clips & Brackets



Intercostals & Short Frames



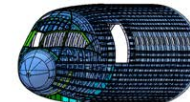
Complex Fittings



Large Details



Sub-Structures



Large Integrated Structures

# *Air Mobility* Economy Of Scale

Nobi Kawamura

John Geriguis

Marie Johnson



# TCC

March 2022

# Forward Looking Statements

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This document contains “forward-looking statements” within the meaning of the “safe harbor” provisions of the Private Securities Litigation Reform Act of 1995, including but not limited to, statements regarding Joby’s intentions and plans. Forward-looking statements give Joby’s current expectations and projections relating to our financial condition, results of operations, plans, objectives, future performance and business. You can identify forward-looking statements by the fact that they do not relate strictly to historical or current facts. These statements may include words such as “anticipate”, “estimate”, “expect”, “project”, “plan”, “intend”, “believe”, “may”, “will”, “should”, “can have”, “likely” and other words and terms of similar meaning in connection with any discussion of the timing or nature of future operating or financial performance or other events. All forward-looking statements are subject to risks and uncertainties that may cause actual results to differ materially from those that we expected, including: Joby’s limited operating history and history of losses; its ability to launch its aerial ridesharing service and the growth of the urban air mobility market generally; Joby’s plans to operate a commercial passenger service beginning in 2024; the competitive environment in which it operates; its future capital needs; its ability to adequately protect and enforce its intellectual property rights; its ability to effectively respond to evolving regulations and standards relating to its aircraft; its reliance on a third-party suppliers and service partners; uncertainties related to Joby’s estimates of the size of the market for its aircraft and future revenue opportunities; and other important factors discussed in the Company’s final prospectus and definitive proxy statement, dated April 2, 2021, filed with the Securities and Exchange Commission (the “SEC”), as updated by the factors disclosed in the section titled “Risk Factors” in its Current Report on Form 8-K filed with the SEC on August 16, 2021, and in other reports the Company files with or furnishes to the SEC. Any such forward-looking statements represent management’s estimates and beliefs as of the date of this press release. While Joby may elect to update such forward-looking statements at some point in the future, it disclaims any obligation to do so, even if subsequent events cause its views to change.





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## A Decade of Engineering

Our aircraft is designed to meet the uncompromising safety standards set by the FAA and other global aviation regulators. With more than a decade of dedicated engineering, prototyping, and flight testing behind us, we're now engaged in a multi-year testing program with the FAA to certify the vehicle for commercial operations.

# "Save a billion people an hour a day"



# Providing Services at Affordable Price

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Focus on the Total Cost of Ownership

# How?

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## Needs for Process Enhancements

- ◇ *Reduce touch labor*
- ◇ Increase throughput
- ◇ Decrease footprint
- ◇ Reduce takt time

# Reduce Touch Labor

- ◆ Automated processes
- ◆ In-situ inspections
- ◆ In-situ repairs
- ◆ Digital Twin
- ◆ Eliminate the variables



# Examples on Light Weight Developments with Multi-Material Approach for Automotive Bodies

# Progress of CFRP technology for Body Parts

(Production volume) Limited Small Large

## Process

- Pre-preg
- **RTM**
- **C-SMC**
- **TSF**
- 3D Weaving

- Pre-preg
- VaRTM

- **RTM**
- **C-SMC**

2017



**LEXUS**

**LC**

Prius PHV



**LFA**



**GSF**



**RC F**



**IS F**

Mark X

GT86

MIRAI

- **TSF**



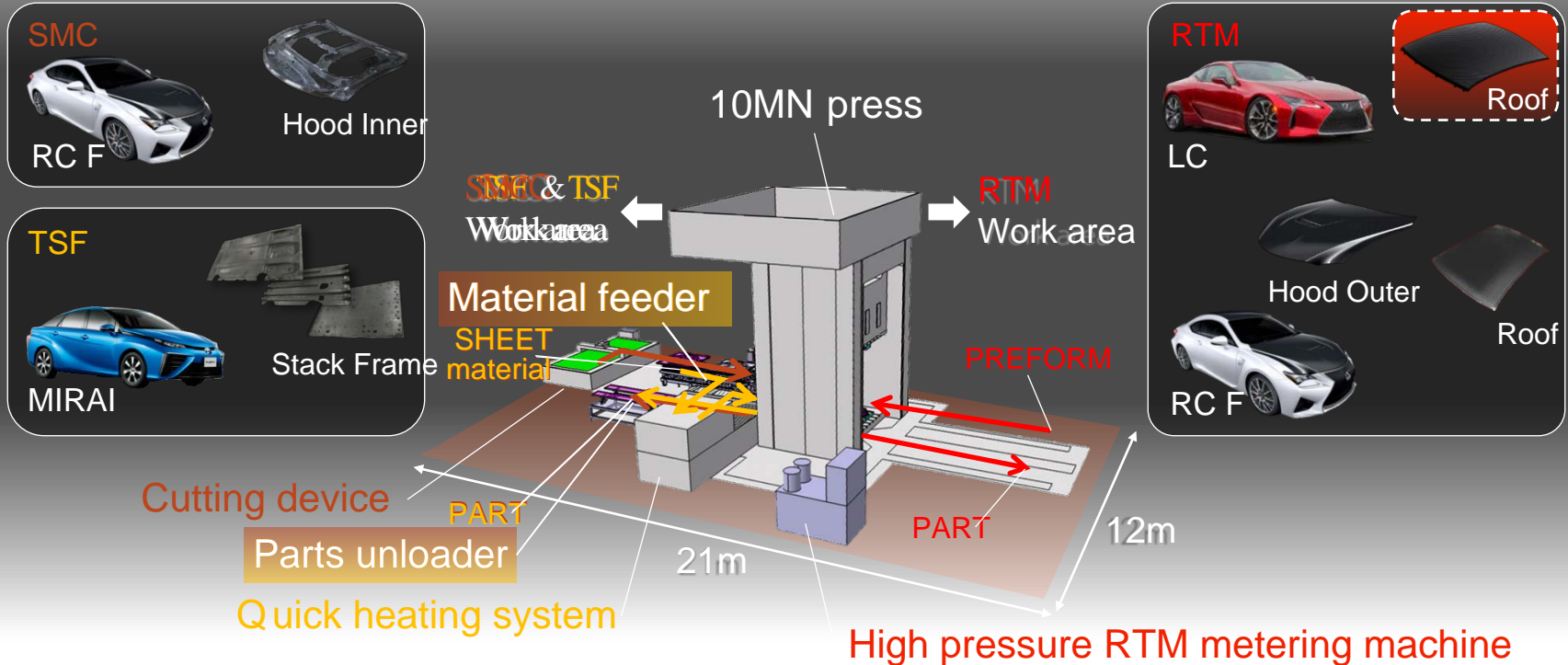
**TOYOTA**

- RTM : Resin Transfer Moulding
- C-SMC : Carbon Sheet Moulding Compound
- TSF : Thermoplastic Stamp Forming

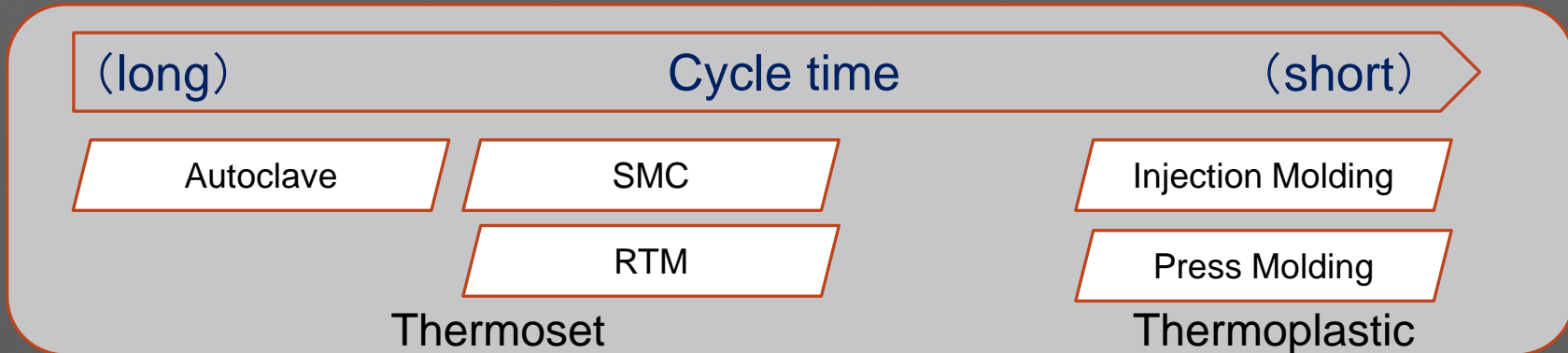
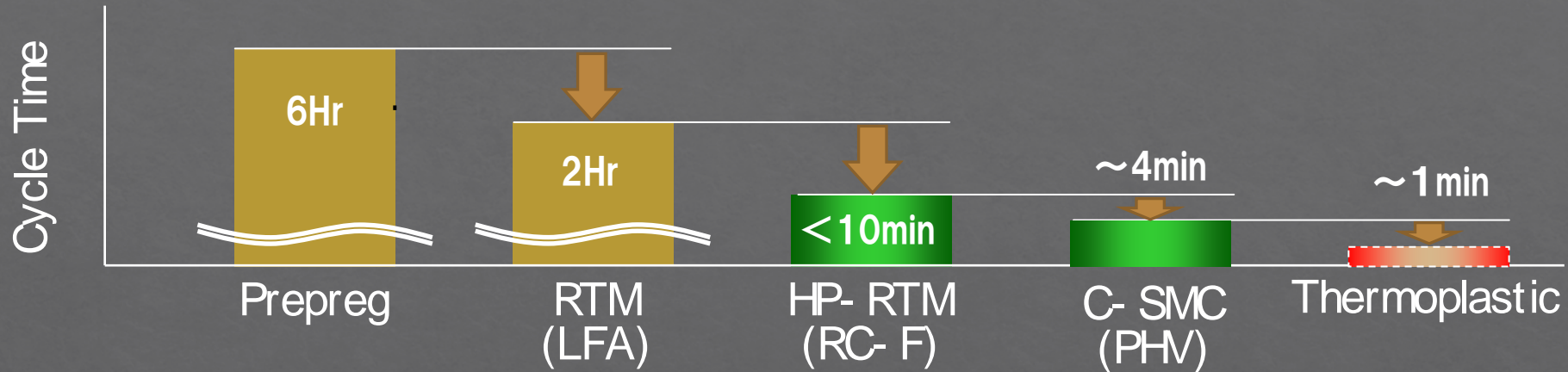


# Flexible Manufacturing Layout

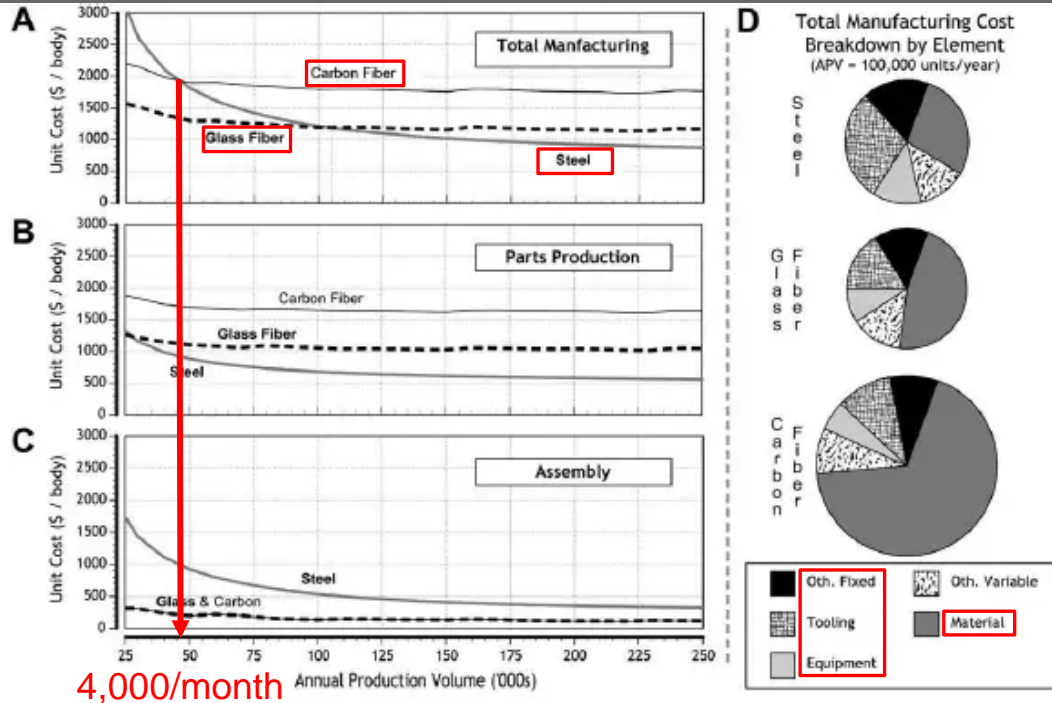
## 3-way Processes in a Single Compact Facility



# Examples of Productivity Enhancement



# Body-in-white Cost Sensitivity to Volume



E.R.H. Fuchs et al. / Composites Science and Technology 68 (2008) 1989–2002

# Key Factors for Automotive Manufacturing

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- ◇ Safety
- ◇ Continuous Improvement
- ◇ Production Efficiency
- ◇ Flexible Manufacturing (Volume and Part Types)
- ◇ Low environmental footprint

# eVTOL economy of scale

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- ◇ High volume production
- ◇ The most economical production
- ◇ Low maintenance cost
- ◇ High operation time
- ◇ Total cost of ownership

# Reduce Material Cost

- ◆ No waste
- ◆ No material expiration
- ◆ No out-time limitations
- ◆ Reduce material purchased by 50%



# Industry improvement opportunities

Improve	Quality inspection methods
Improve	Lay-up time
Improve	Material for AFP
Improve	Weight saving
Improve	Takt time
Improve	Joining Methods

# Attachments



# eVTOL Key Factors:

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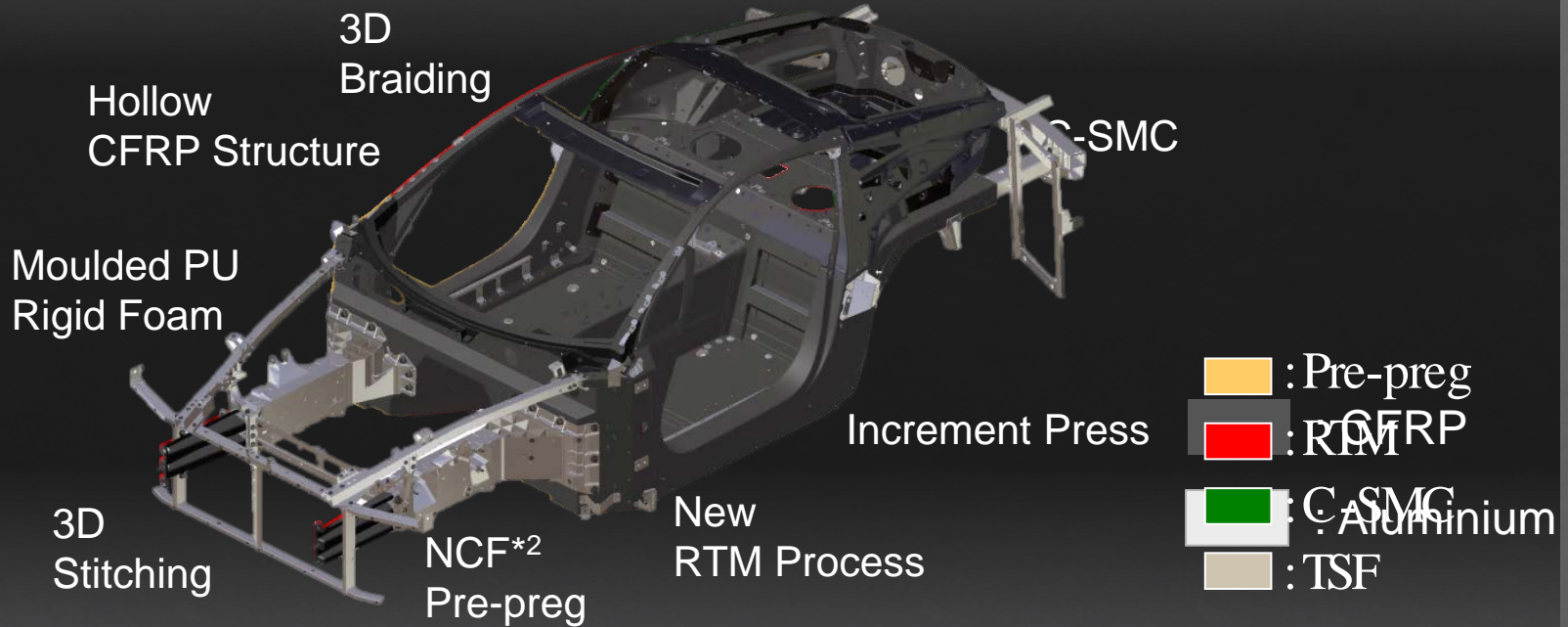
- ◇ Safety is north star.
- ◇ Light-weight is central to achieve maximum range.
- ◇ Production volume expected to be significantly higher than traditional aerospace.
- ◇ Total cost of ownership of an aircraft is a key to success .

# eVTOL performance requirements:

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- ◇ Low noise
- ◇ Flight distance
- ◇ Load capacity
- ◇ Customer comfort

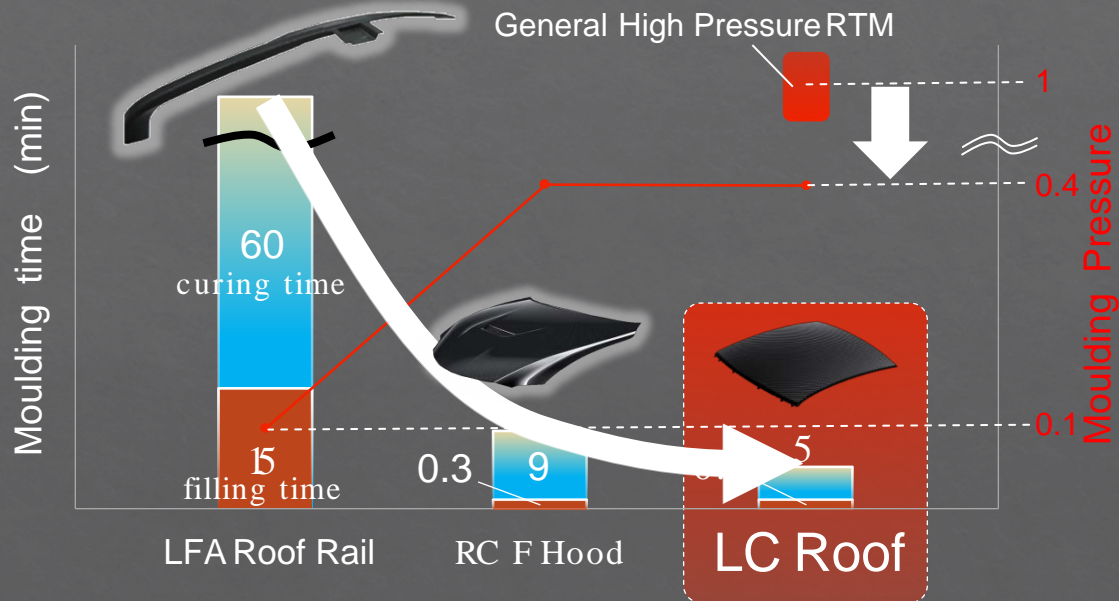
# Development of CFRP Monocoque for Lexus LFA



Developed various materials and processes  
CFRP Cabin and Aluminium Frames

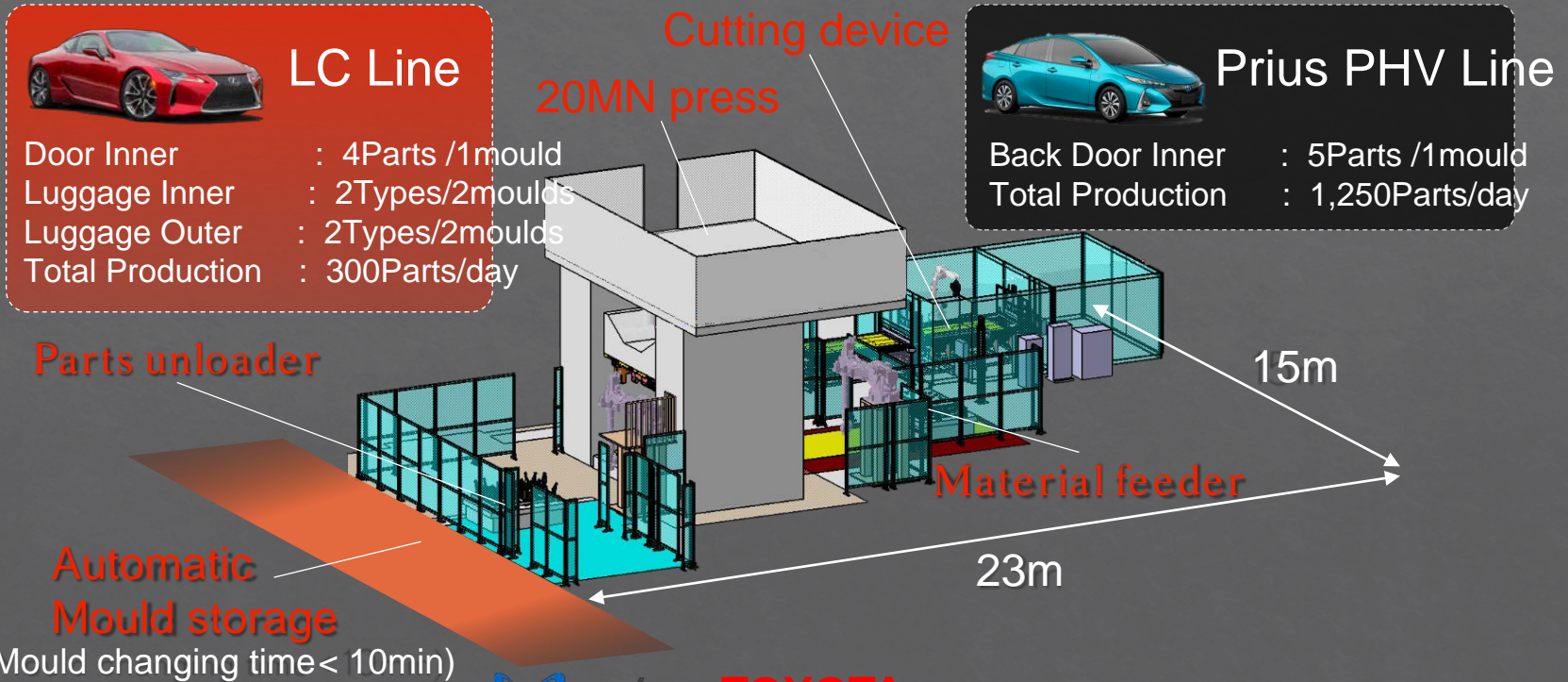
# High-Speed RTM

- ◇ 1. To shorten moulding time by improved resin and impingement mixing process
- 2. To realize compact facility by low pressure moulding



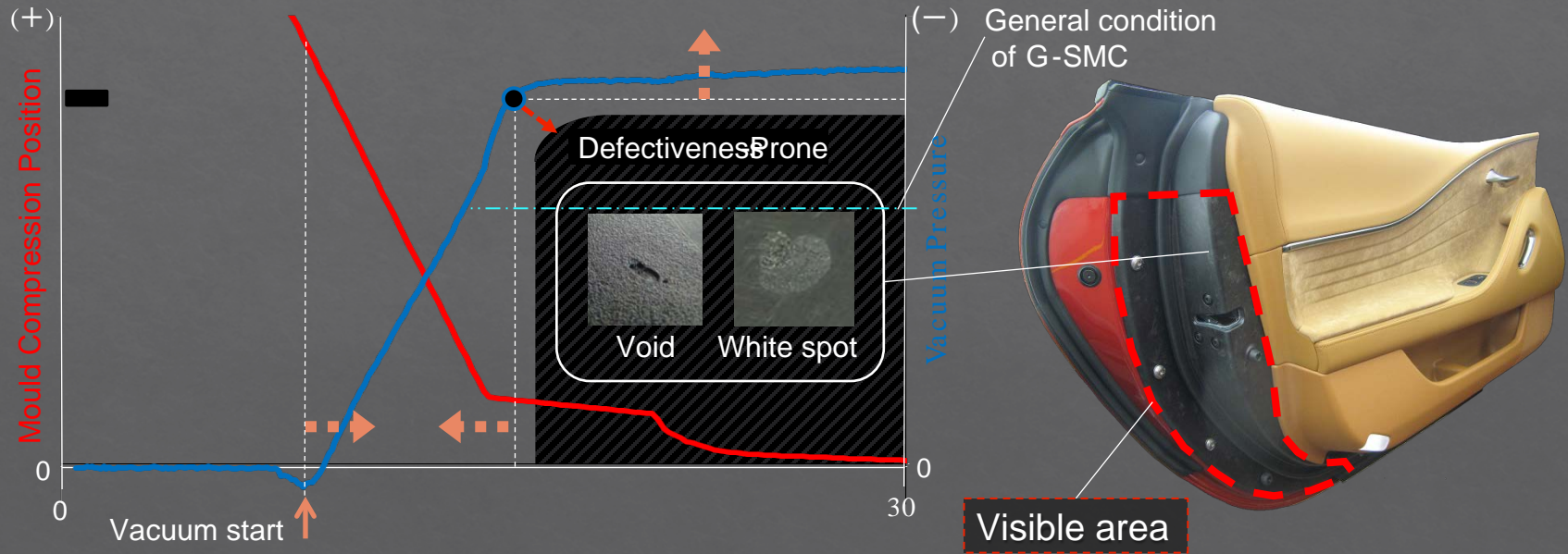
# Carbon-SMC Multiproduct Processing Line

High quality, High productivity

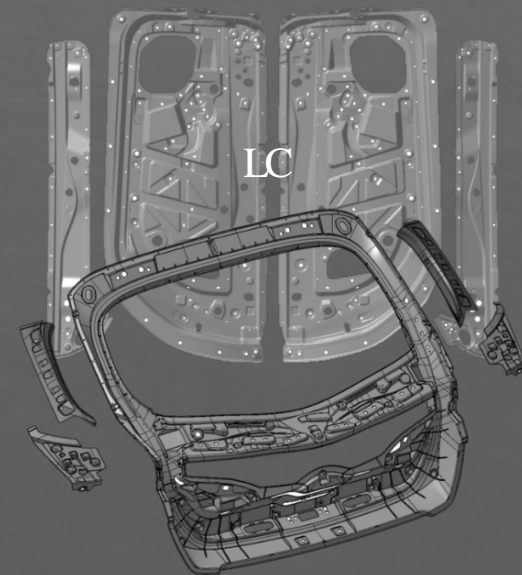
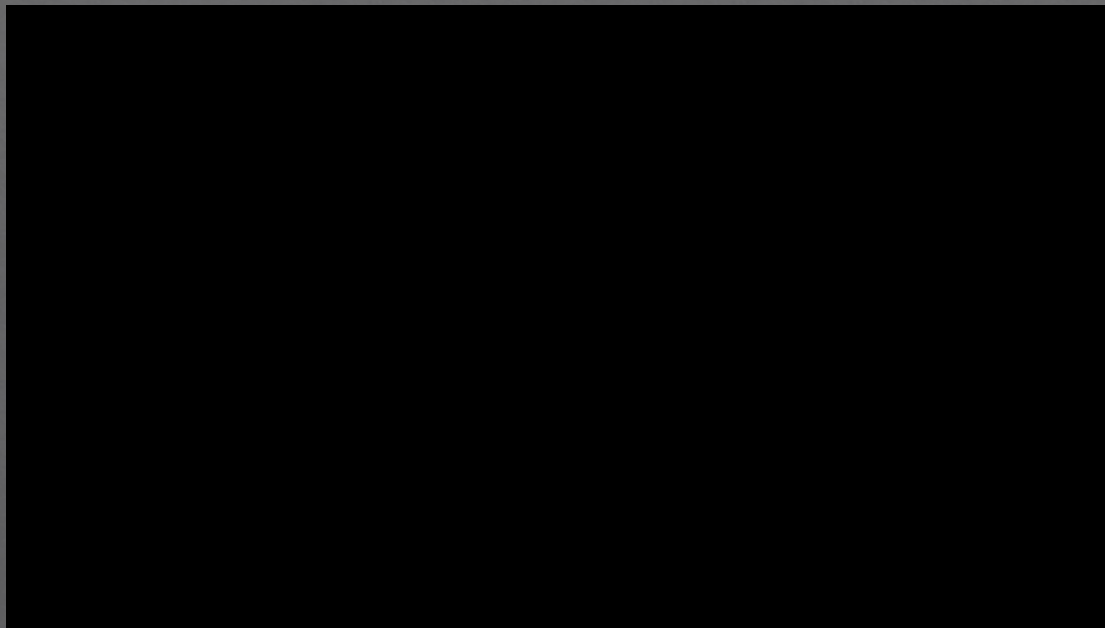


# Out of the Mold Cosmetic Surface

1. Low vacuum pressures cause surface defects
2. Slow vacuum speed causes flow defects



# Family Molding

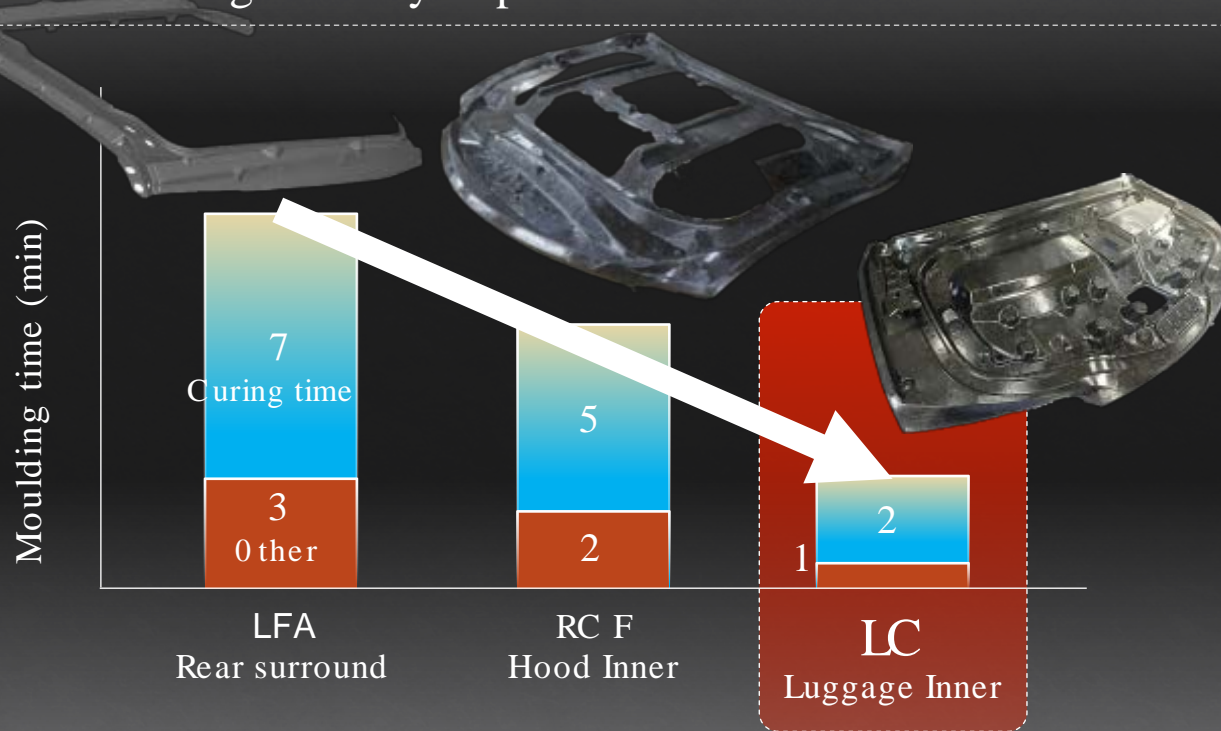


**4 parts** of the Door Inner of LC

**5 parts** of Back Door Inner  
of Prius PHV

# Continuous Improvement on Cycle Time

Shorten Moulding Time by Improved Resin





# Reduce Touch Labor

- ◆ Automated processes
- ◆ In-situ inspections
- ◆ In-situ repairs
- ◆ Digital Twin
- ◆ Eliminate the variables

