NBAA|BACE
OCTOBER 16-18, 2018 · ORLANDO, FL

GENERAL AVIATION 2025:
A supercomputer with wings.

October 16, 2018 From 3:00 to 4:00 PM

Rene Nardi

Work Objective

"Find a need and fill it"

To identify new opportunities to revitalize and expand the 4-to-6-seat aircraft market with the introduction of technologically advanced solutions.

Polling Question #1

In a couple of words, describe what you think light general aviation (piston-engine) would look like in 2025.

Conceptual Analysis Engineering Team

Executive Summary

"The world is changing faster than you think"

- The piston-engine segment is the natural market point of entry for a new class of electric aircraft
- The customers needs for a product that is safer, simpler to operate and more comfortable can be addressed with three key technologies: Electrification, Automation and Autonomy
- We are targeting flying two prototypes by 2021, followed by EIS in 2025
- The market can absorb at least 10,000 aircraft per year, over the first ten years of the program

Sources: P. Diamandis

Market Definition

- General Aviation includes all aviation, other than military and scheduled commercial airlines.
- Supports $ 200+ billion in total economic output and one million jobs, in the US
- It includes over 445.000 aircraft flying worldwide, ranging from 2-seat training aircraft to intercontinental business jets
- Piston-Engine Aircraft is the market segment of interest.

Sources: GAMA 2017 Annual Report

Best-Selling Aircrafts

Cirrus SR 22 T

Cessna 172 S

Piper PA 28 Archer

Diamond DA-40

Tecnan LSA

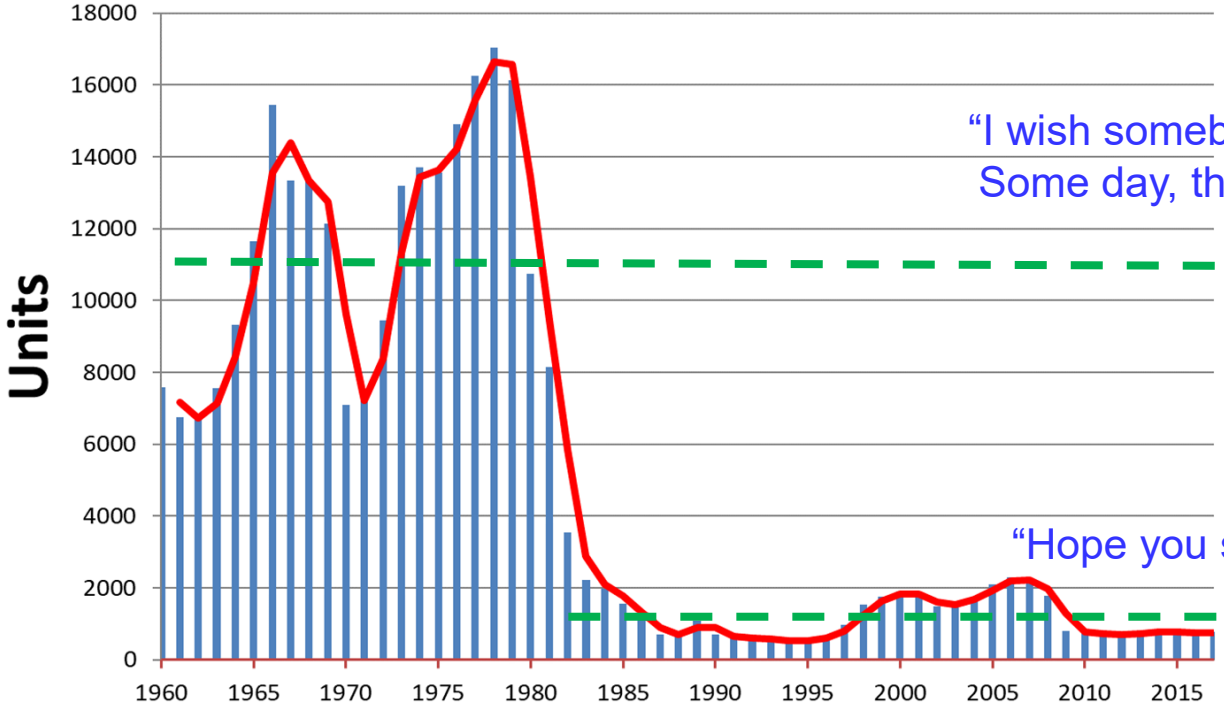
Detailed Discussion

- **Why the piston-engine segment is the right market entry point?**

- **Unprecendent innovation** **Convergence of Technologies**

- **Project Roadmap** **How large is the market ?**

Piston-Engine aircraft sales has been stagnant for decades



'60s and '70s
"I wish somebody would have told me babe
Some day, these will be the good old days"

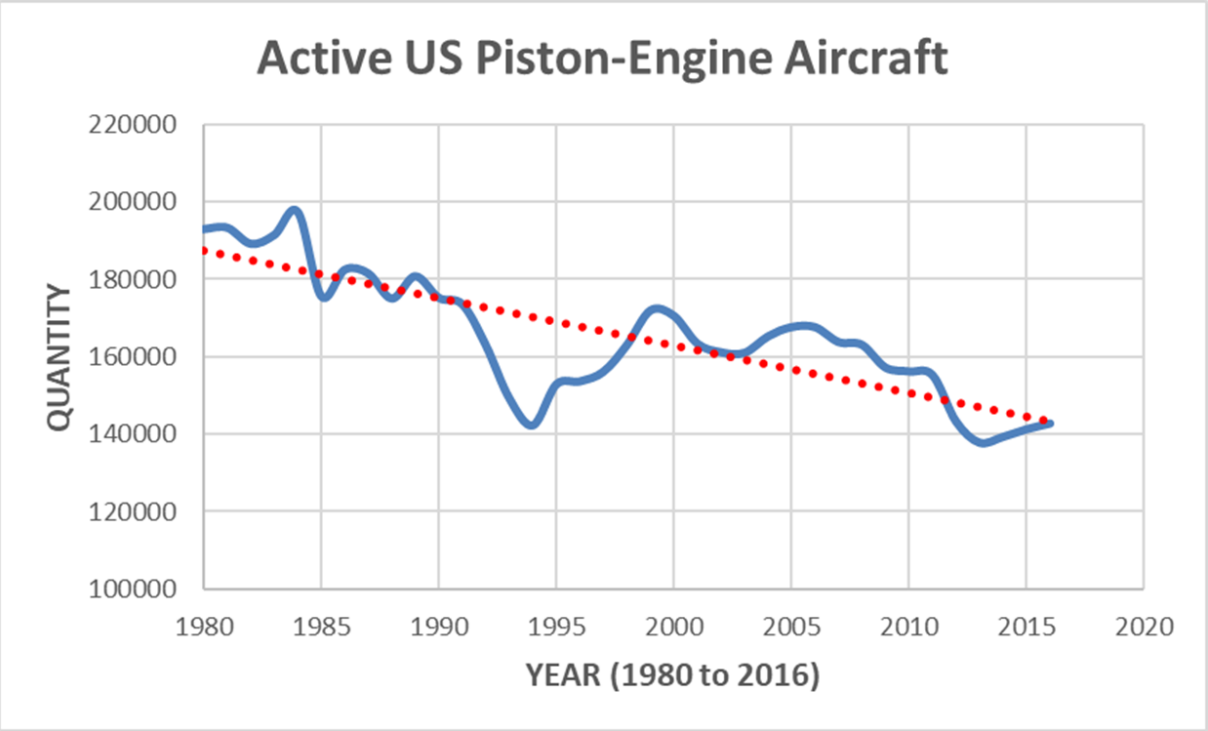
11,000 / year

"Hope you still love '80s and '90s sales"

1,200 / year

Sources: GAMA 2017 Annual Report – Macklemore/Kesha - InStyle

The overall US piston-engine aircraft fleet is in sharp decline



Year	Qty
1980 -	193,000 a/c
2017 -	142,000 a/c
Delta -	51,000 a/c

The net average rate of reduction is 1,200 a/c per year

Sources: GAMA 2017 Annual Report

Absence of significant innovation

Beech Bonanza - **1947**

Cessna 172 - **1955**

Piper P 28 - **1960**

Tecnan - **1993**

Cirrus - **1995**

Diamond - **1997**

Polling Question #2

In a nutshell, what are the most important topics to reinvigorate a passion for light general aviation (piston-engine).

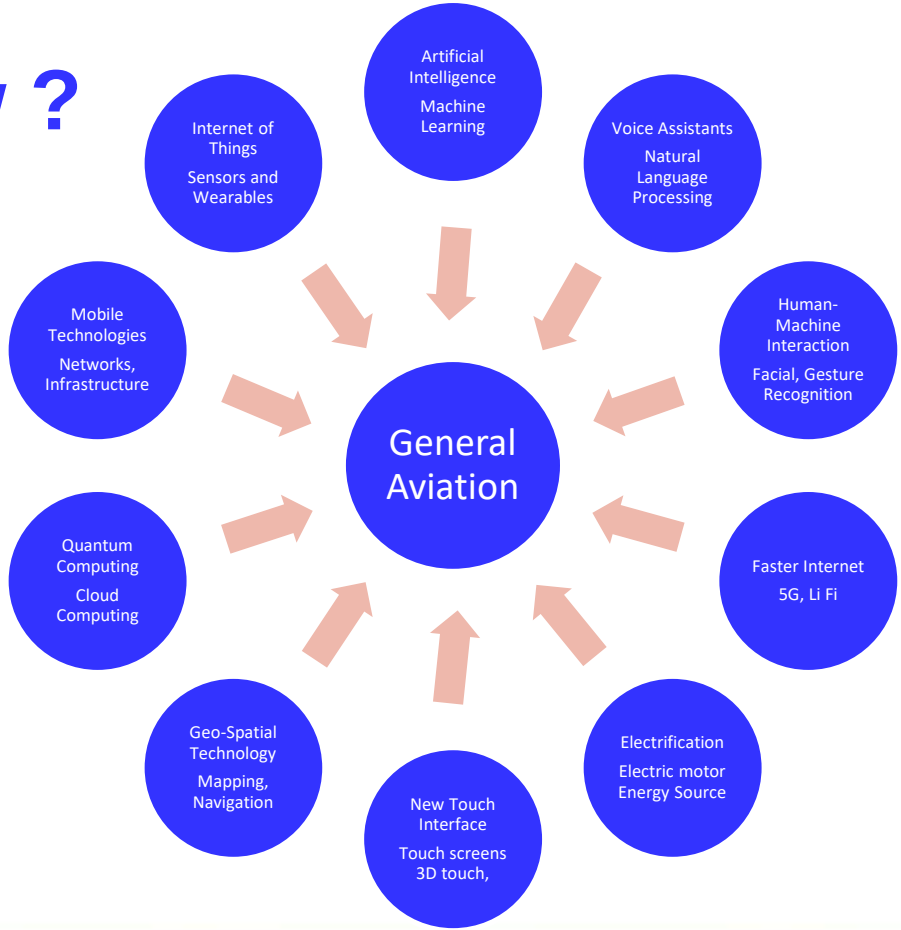
Detailed Discussion

- Why the piston-engine segment is the right market ?

- **Why now?** **Convergence of Technologies**

- Project Roadmap How large is the market ?

Why now ?

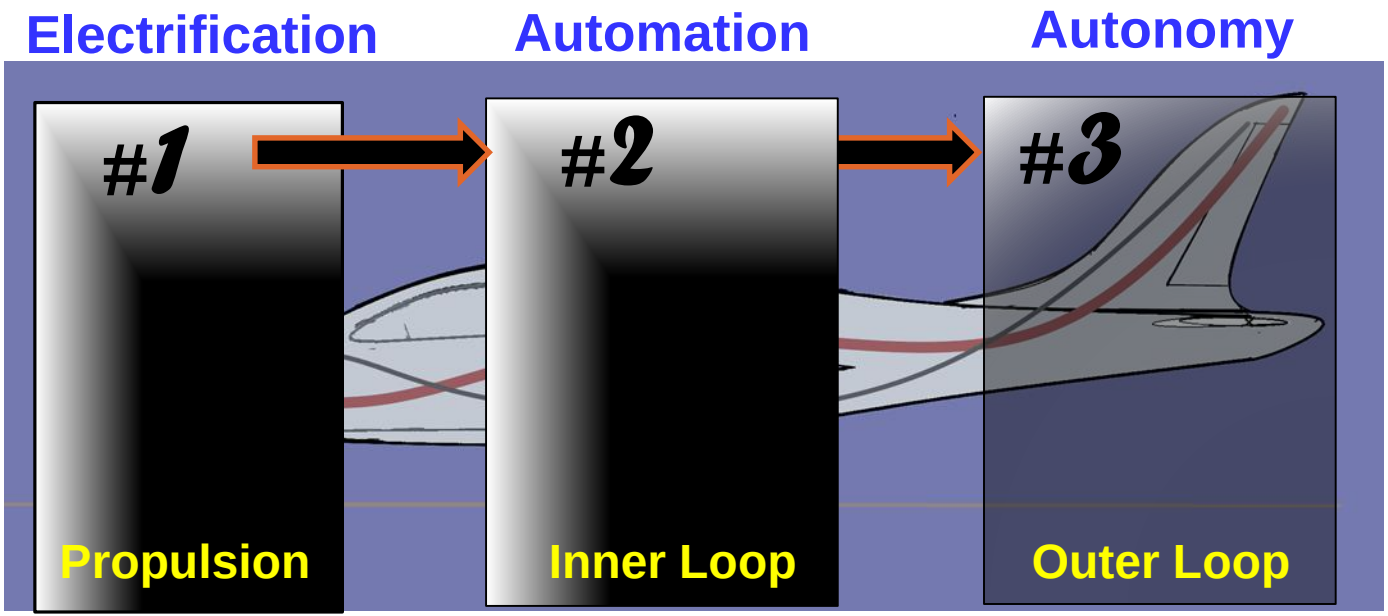


Disruptive technologies for the next decade

A number of trends are coming together

Convergence of Technologies

Convergence of Technologies



More reliable, lower costs to operate and sustain, reduced noise and vibration.

Process automation, Flight envelop protection to prevent CFIT and loss of control.

Autonomous ground maneuvers; Automated take-off and landing; Autonomous flight.

Automation and Autonomy

“When everything is intelligent”

AUTOMATION

Artificial Intelligence / Machine learning

Process automation. Anything that is repetitive or has a pattern driven by data will be replaced by AI.

Check List

Before Starting Engine

1. Preflight ..... Complete
2. Seats and Seat Belts .... Adjust and Lock
3. Brakes ..... Test and Set
4. Cowl Flaps ..... Open
5. Fuel Selector ..... Fullest Tank
6. Lights ..... OFF
7. Circuit Breakers ..... Check
8. Clock ..... Set
9. Altimeter ..... Set
10. Controls ..... rect
11. Flaps ..... k
12. Trim ..... Se
13. Radios and Electrical Equipment
14. Master Switch
15. Landing Gear ..... Handle Neu
.....Green DN Light O
16. Landing Gear Lights, Horn Press to Tes

Starting Engine

1. Anti-collisi ..... ON
2. Mixture ..... Full Rich
3. Propelle ..... High RPM
4. Throtti ..... Full Open
5. Prop ea ..... CLEAR
6. A Pump Switch High for 5 Sec.
7. l Pump Switch ..... OFF
8. e 50%
9. on Key ..... Start
10. ottle ..... Reduce to Idle
11. l Pressure ..... Check
12. Radios .....ON, Check 121.5
13. Transponder ..... Standby
14. Fuel Selector ..... Switch Tanks for Taxi
15. Brakes ..... OFF
16. Toe Brakes ..... Check

AUTONOMY

Human-Machine Interaction

Face recognition, Gesture, Voice Assistants, Natural Language Processing, Touch Interface, 3D touch screens.

Sources: Sean Moffitt, Wikibrands; Byton

Polling Question #3

How comfortable do you feel with an autonomous aircraft ?

Scale 1 to 5

1 – I will not fly in one and 5 – Very comfortable

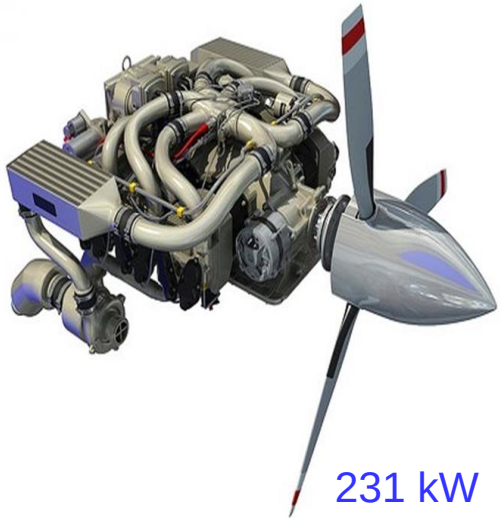
Electrification - Propulsion and Energy Systems

"Somethin' tells me I am into something good"

- **Electric Motors:** high efficient electric motors driving open rotors, ducted fans or a propeller.
- **Power Supply:** diverse energy storage devices - batteries, capacitors, fuel-cells or ?????
- **Configurations:** high level of comfort for passengers, and new options to properly integrate the electric system components into the airframe.

A tale of two powerplants

Continental IO-550		Siemens SP-260
231 kW	**Power**	260 kW
200 kg	**Weight**	50 kg
1 kW/kg	**Power to Weight**	5 kW/kg
30 %	**Efficiency**	95 %
By the hundreds	**Moving Parts**	A dozen



The devil is in the details... batteries.

	Specific Energy :
AVGAS 100LL	12,300 Wh / kg
Lithium-Ion battery:	250 Wh / kg

AVGAS to Li-Ion **Specific Energy Ratio**: **50**

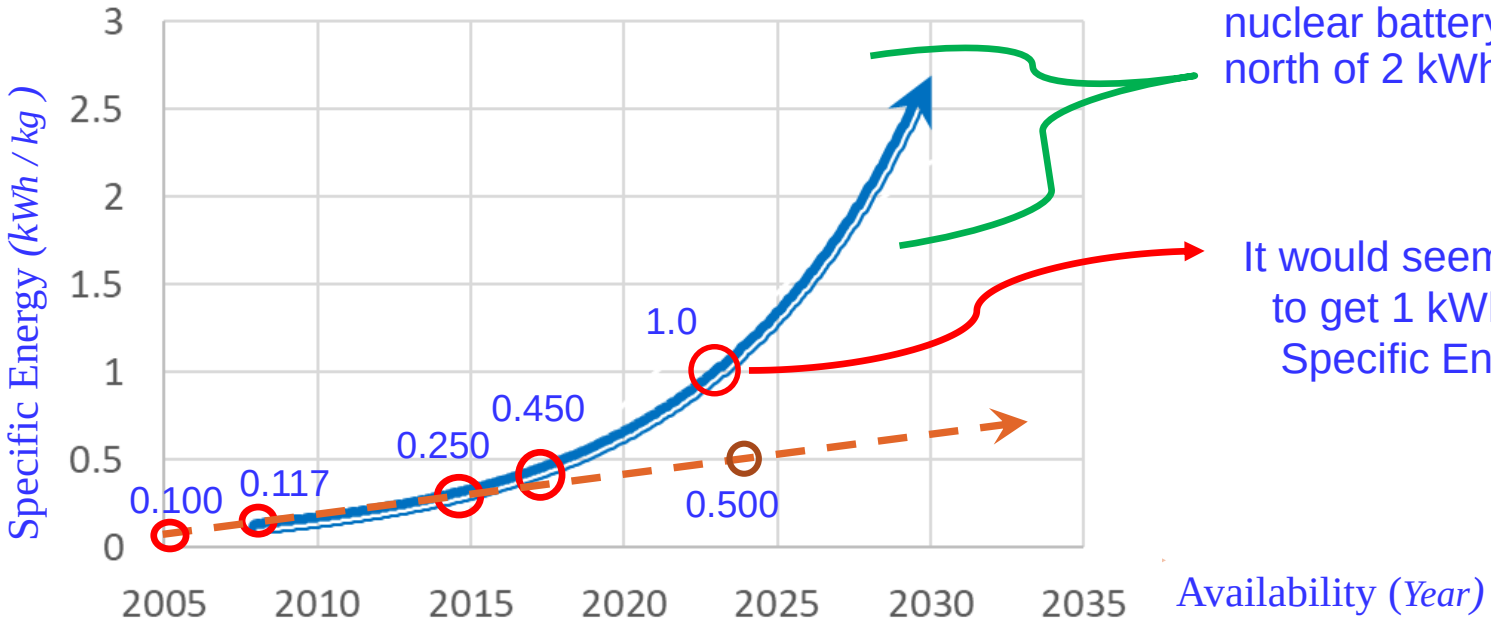
Efficiency:		Specific Energy:	
Piston Engine:	29%	AVGAS:	3.567 Wh / kg
Electric Motor :	95%	Li-Ion battery:	237 Wh / kg

AVGAS to Li-Ion **Specific Energy Ratio : 15**

2018 Lithium-Metal batteries rated at 450 Wh/kg ??.

Specific Energy ratio : ~ 8

Exponential Growth ?

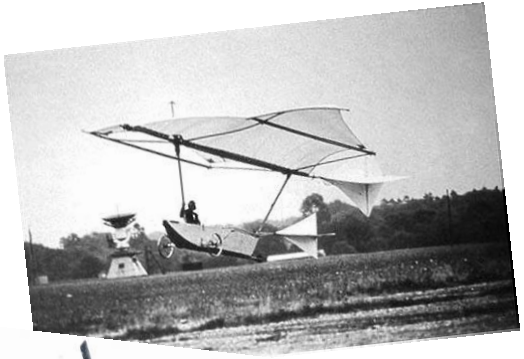


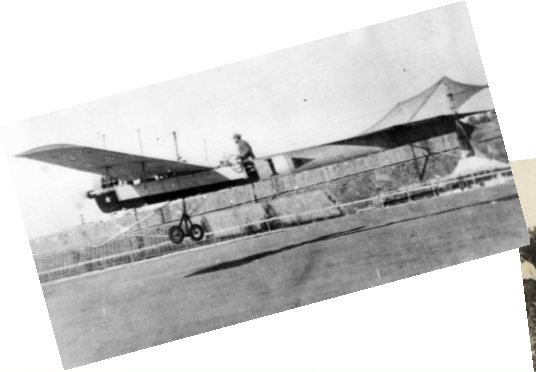
Lithium sulfur, lithium seawater, fuel cells, super-capacitors, nuclear battery, etc, delivering north of 2 kWh/kg.

It would seem we are on track to get 1 kWh / kg , by 2022
Specific Energy Ratio ~ 4

Configuration - 100 years ago

“Those magnificent men in their flying machines “





Sources: Ron Goodwin, 1965

Propulsion System

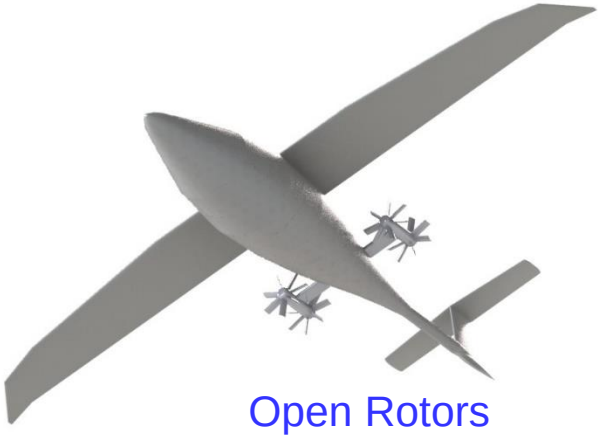
Single Propeller

Electric Ducted-Fans

Electric Open-Rotors

Fully-Electric Aircraft Architecture

Boundary Layer Ingestion
1 x 260 kW



Open Rotors
4 x 65 kW = 260 kW

Electric-Ducted Fans
2 x 130 kW = 260 kW

High Level Requirements

Destination trip: simulates a transportation activity between two regional airports
Trip distance: 270 NM with 45 minutes reserve.

Trip Distance: 270 NM Cruise Speed: 190 KTAS
Flight Time: xxxxx (min.) Trip Time: xxxxx (min.)
Recharge Time: xxxxx (min.) Total Energy: xxxxx (KWh)

Aircraft interior for 4–5 occupants

Energy source rated at 1 kWh/kg

Electric motors rated at 5 kW/kg each

Aircraft preview

What if ????

270 NM + 45 min reserve

Empty Weight:	2,400 lbs.
Fuel load:	250 lbs.
4 Pax:	800 lbs.
Operating Weight:	3,450 lbs.
MTOW:	3,800 lbs.

Empty Weight:	2,050 lbs.
Battery load:	1,000 lbs.
4 Pax:	800 lbs.
Operating Weight:	3,850 lbs.
MTOW:	3,850 lbs.

The electric airplane is 400 lbs. or 12% heavier

Detailed Discussion

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- Unprecendent innovation Convergence of Technologies

- Project Roadmap How large is the market ?

Horizon of Innovation

Turbo-Prop

Piston

2018
0.25 kWh/kg

2 Pax – 60 kW

2025
1 kWh/kg

4 Pax – 225 kW

2030
2 kWh/kg

6 Pax – 2 x 225 kW

2030+
3 kWh/kg

6 Pax – 450 kW

20??
3+ kWh/kg

8 Pax – 2 x 450 kW

Polling Question #4

What would be the total annual sales of new small general aviation aircraft considering that we could get back to 1960/1970 sales volume?

A. – no more than US$ 1 billion

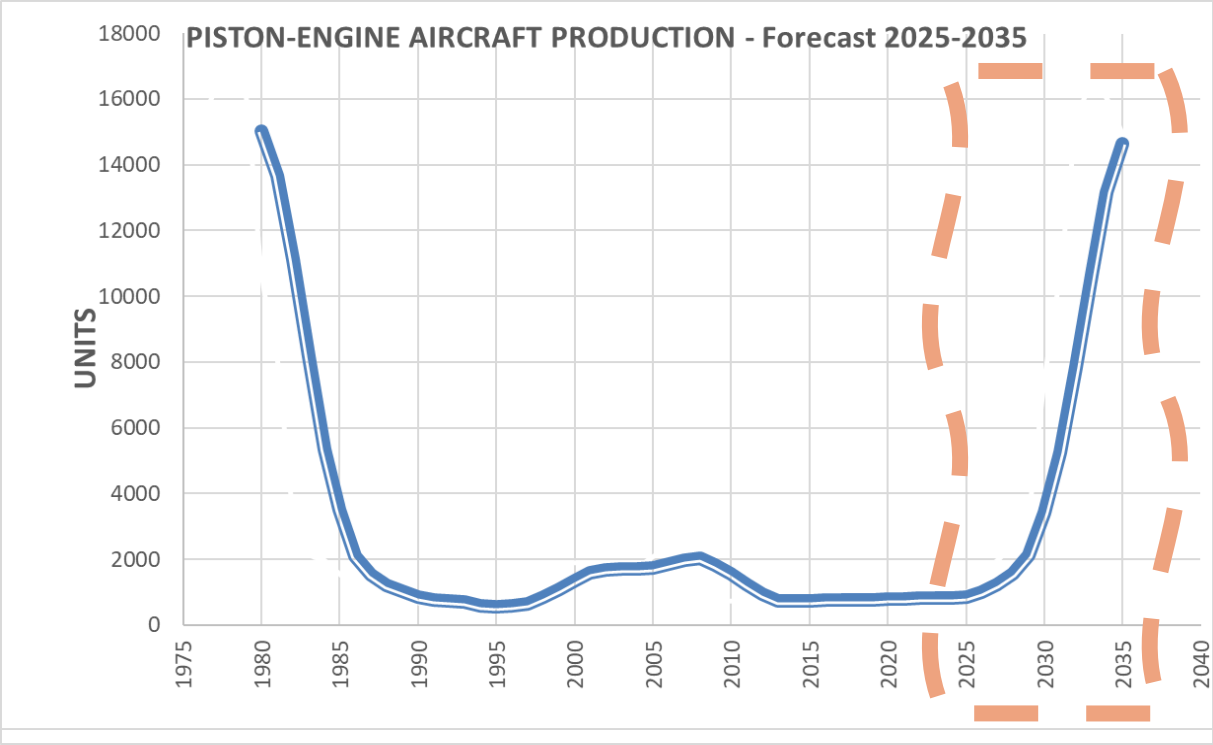
B. - $ 2 billion

C. - $ 3 billion

D. –$ 4 billion

E. – more than $ 5 billion

Moonshot thinking



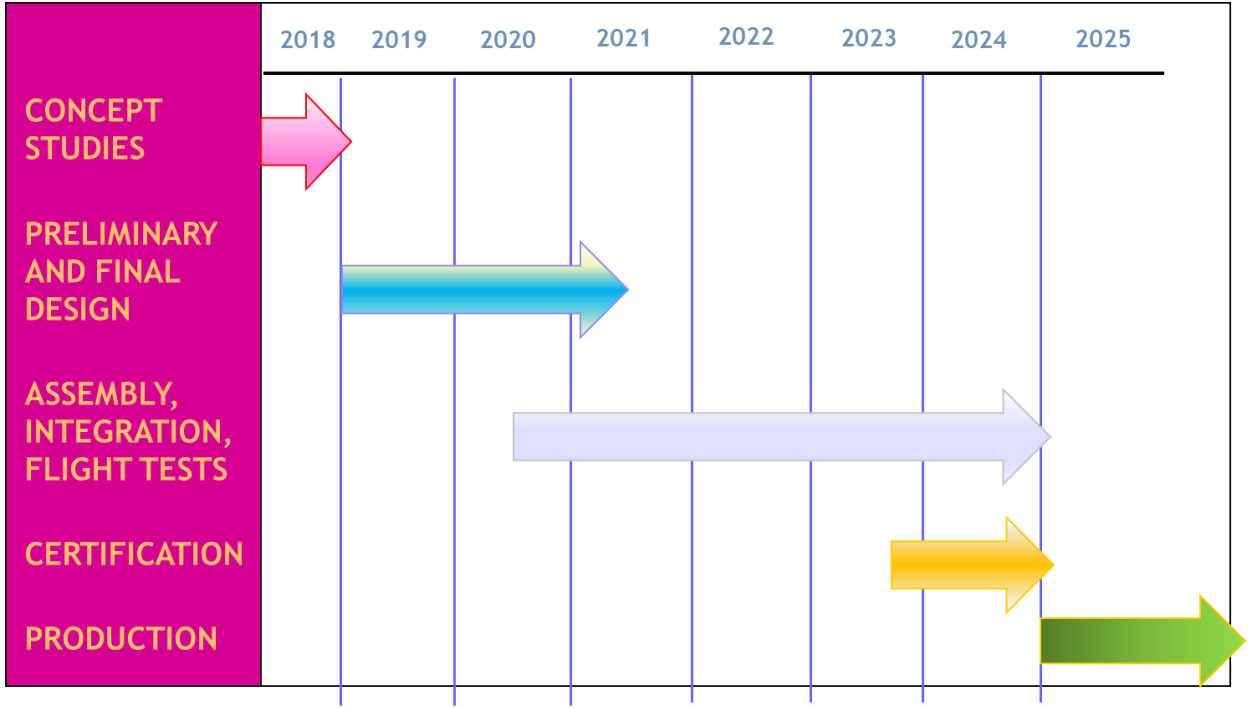
10x increase on production rate

Return to 1960-1970 sales level

100,000 a/c to be delivered between 2025 and 2035

US$ 70 billion of accumulated revenue over 10-year

Project Roadmap – 2018-2025



Two years to design and build the first prototype

First flight in 2021

Four years of flight test

Formally launch the program in 2023

Start production in 2025

Conclusions

"This is not an evolution of your product. It's a substitution of your product"

- There is a need for a new product that is safer, simpler to operate and more comfortable
- Electrification, Automation and Autonomy are the key technologies needed for business transformation
- EIS in 2025 or as soon as the 1 kWh/kg energy source becomes available
- China, India and Africa are newcomers to a market that can demand as many as 10,000 aircraft per year, for as long as 10 years
- Total market value would reach US$ 70 billion in 10 years, not considering MRO

Sources: John Casesa

Thank you

Rene Nardi
renenardi@hotmail.com
+1 912 401-6453

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