GENERAL AVIATION 2025: A supercomputer with wings.

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

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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.

Sources: Henry J. Kaiser
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

Diamond DA-40

Piper PA 28 Archer

Tecnan LSA
Detailed Discussion

• Why the piston-engine segment is the right market entry point?
  • Unprecedented 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.

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

Sources: enter sources here
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

Sources: Sean Moffitt, Wikibrands
Convergence of Technologies

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

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

**Autonomy**
- 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  .......................... Free & Correct
11. Flaps  ........................................ Check
12. Trim  ........................................... Set
13. Radios and Electrical Equipment  ... OFF
14. Master Switch  ......................... OFF
15. Landing Gear  ......................... Green DN Light ON
16. Landing Gear Lights, Horn  Press to Test

Starting Engine

1. Anti-collision  ......................... ON
2. Mixture  .................................. Full Rich
3. Propeller  .......................... High RPM
4. Throttle  .................................. Full Open
5. Propeller  ......................... CLEAR
6. Auxiliary Pump Switch  High for 5 Sec.
7. Auxiliary Pump Switch  OFF
8. Throttle  ....................................... 50%
9. Ignition Key  .......................... Start
10. Throttle  ....................................... Reduce to Idle
11. Oil 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.

Sources: Gerry Goffin and Carole King
A tale of two powerplants

Continental IO-550

- Power: 231 kW
- Weight: 200 kg
- Power to Weight: 1 kW/kg
- Efficiency: 30%
- Moving Parts: By the hundreds

Siemens SP-260

- Power: 260 kW
- Weight: 50 kg
- Power to Weight: 5 kW/kg
- Efficiency: 95%
- Moving Parts: A dozen

Sources: enter sources here
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:

Piston Engine: 29%  
Electric Motor: 95%

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

Open Rotors
4 x 65 kW = 260 kW

Electric-Ducted Fans
2 x 130 kW = 260 kW

Boundary Layer Ingestion
1 x 260 kW
High Level Requirements

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

Aircraft interior for 4–5 occupants

Energy source rated at 1 kWh/kg

Electric motors rated at 5 kW/kg each

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

High aspect ratio, laminar flow wing

Advanced composite manufacturing for complex-curved fuselage

Conformable interior, wide cabin for four occupants

Two electric ducted fans

T-tail

Two sets of batteries in the wings and a third emergency battery on the fuselage

Sources:
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

Sources: enter sources here
Detailed Discussion

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

• Unprecedented innovation Convergence of Technologies

• Project Roadmap How large is the market?
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

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