Model Identification and control of a Convertible Aircraft (MICA)

ANR young researcher program

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AGENCE NATIONALE DE LA RECHERCHE ANR

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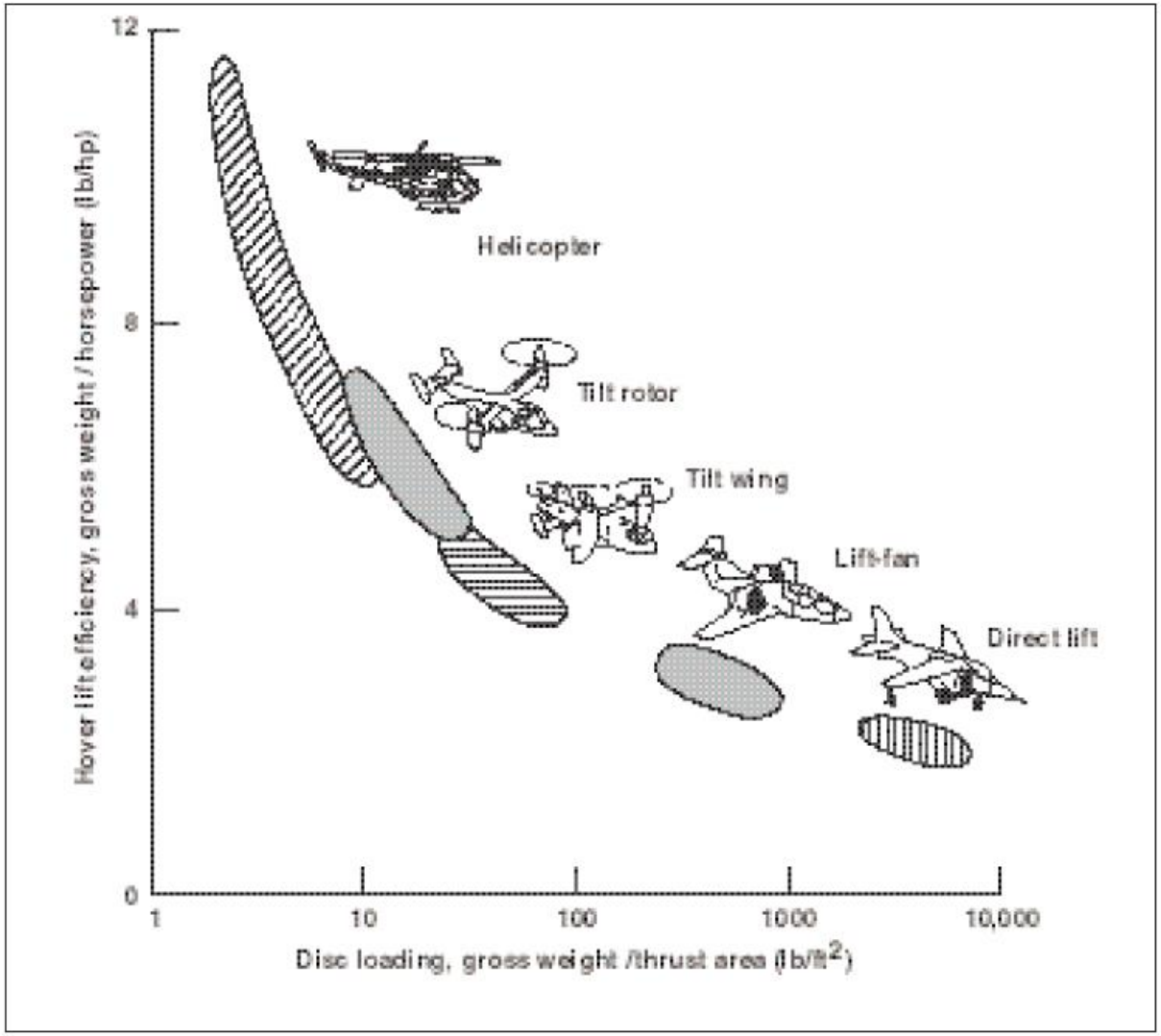
Outline of the presentation

1. Introduction and objectives
2. Proposed research program
3. Participants

Introduction - Background



Hover vertical lift efficiency as a function of disc loading

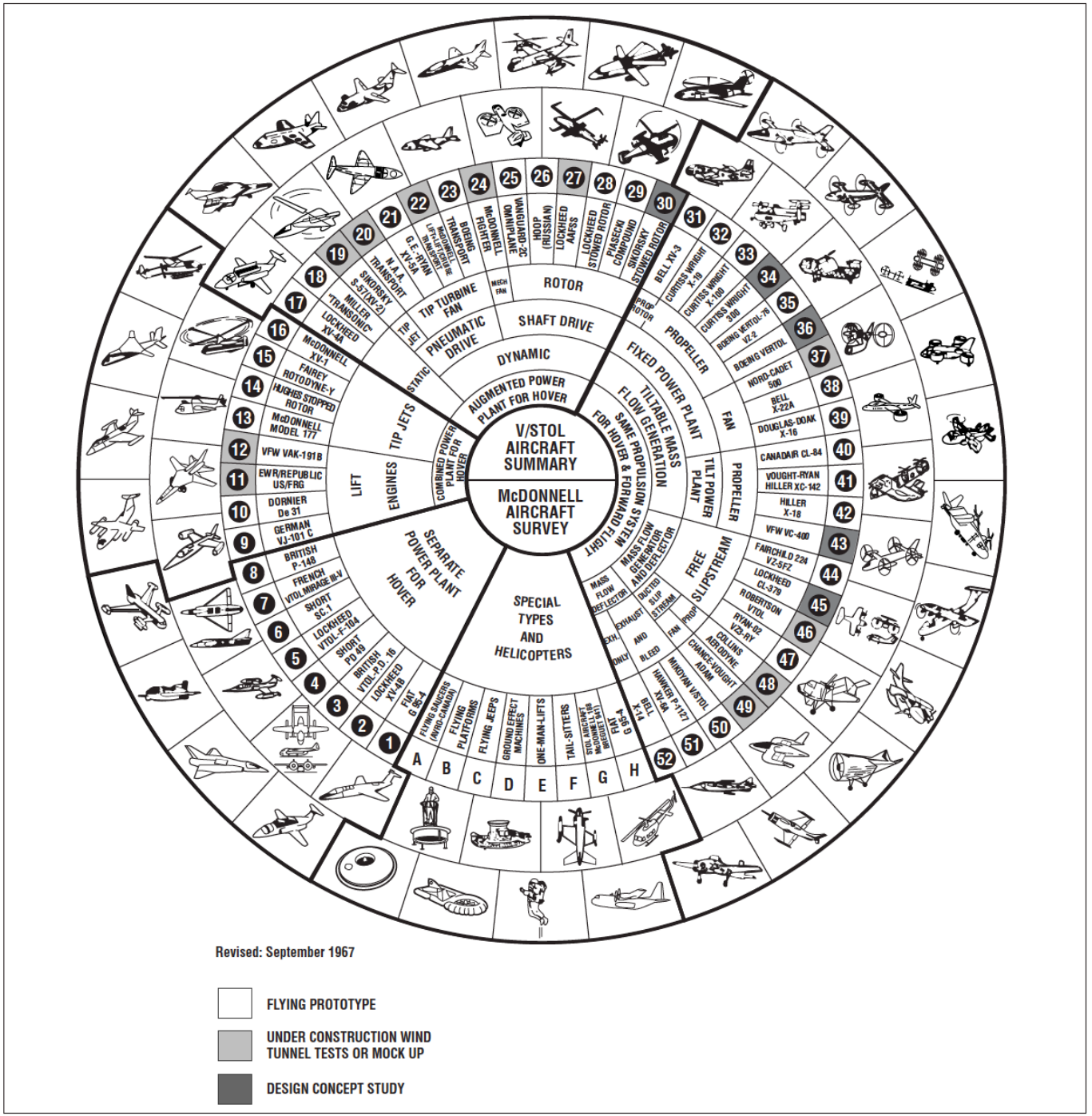
https://history.nasa.gov/monograph17.pdf

Introduction - Background

Illustration of vertical and short takeoff and landing (V/STOL) aircraft developed
by the McDonnell Aircraft Company in the mid-1960s.

Mission requirements:

- Significant hover duration
- Low speed agility & maneuvering
- Speed/range greater than current helicopter



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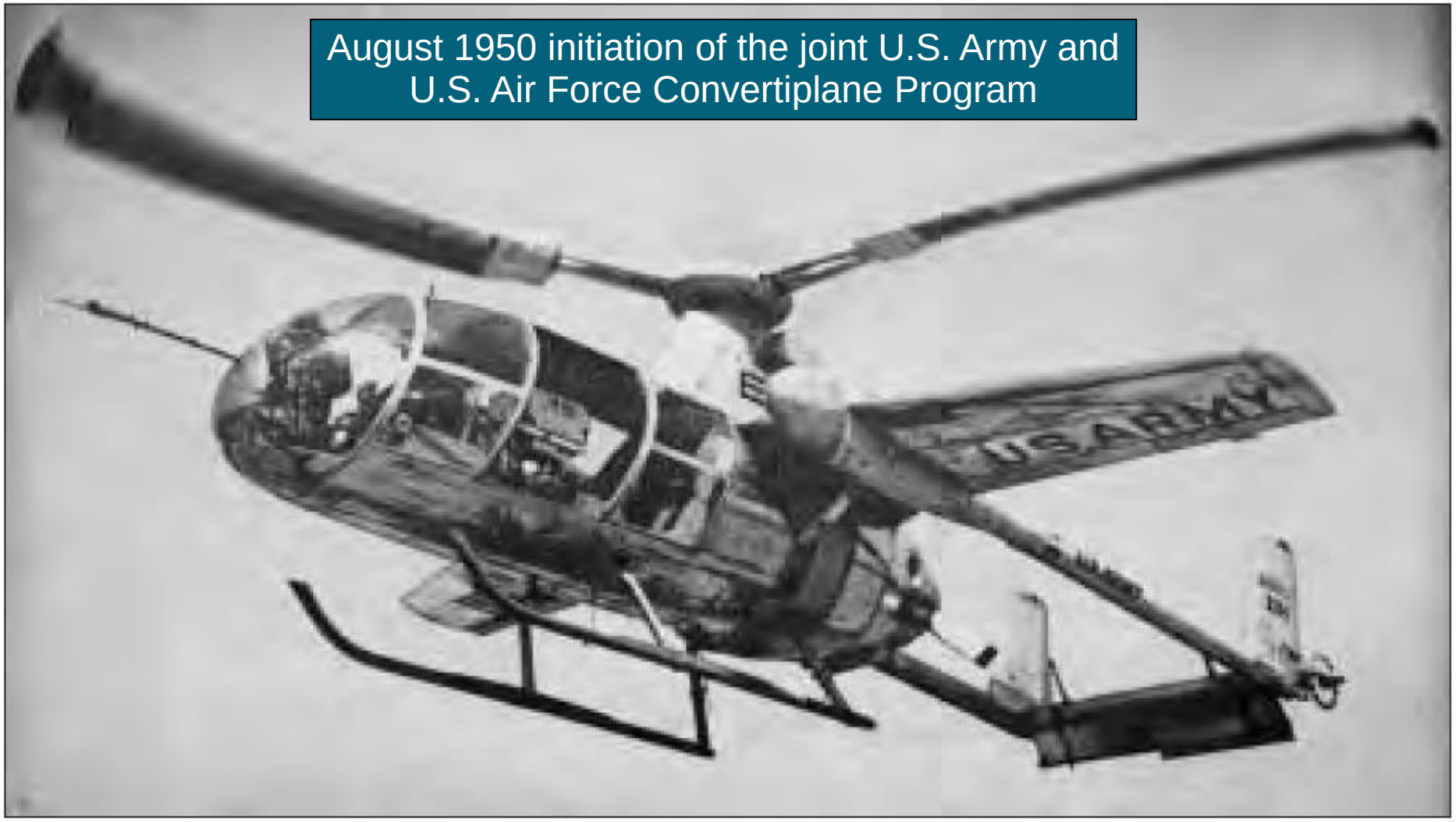
Introduction - Background

August 1950 initiation of the joint U.S. Army and U.S. Air Force Convertiplane Program



McDonnell XV-1compound helicopter (Boeing Photograph AD98-0209-13)

The XV-1 achieved a speed of 200 mph in 1955

R. W. Prouty's February 1984 Rotor and Wing International article "From XV-1 to JVX—A Chronicle of the Coveted Convertiplane."

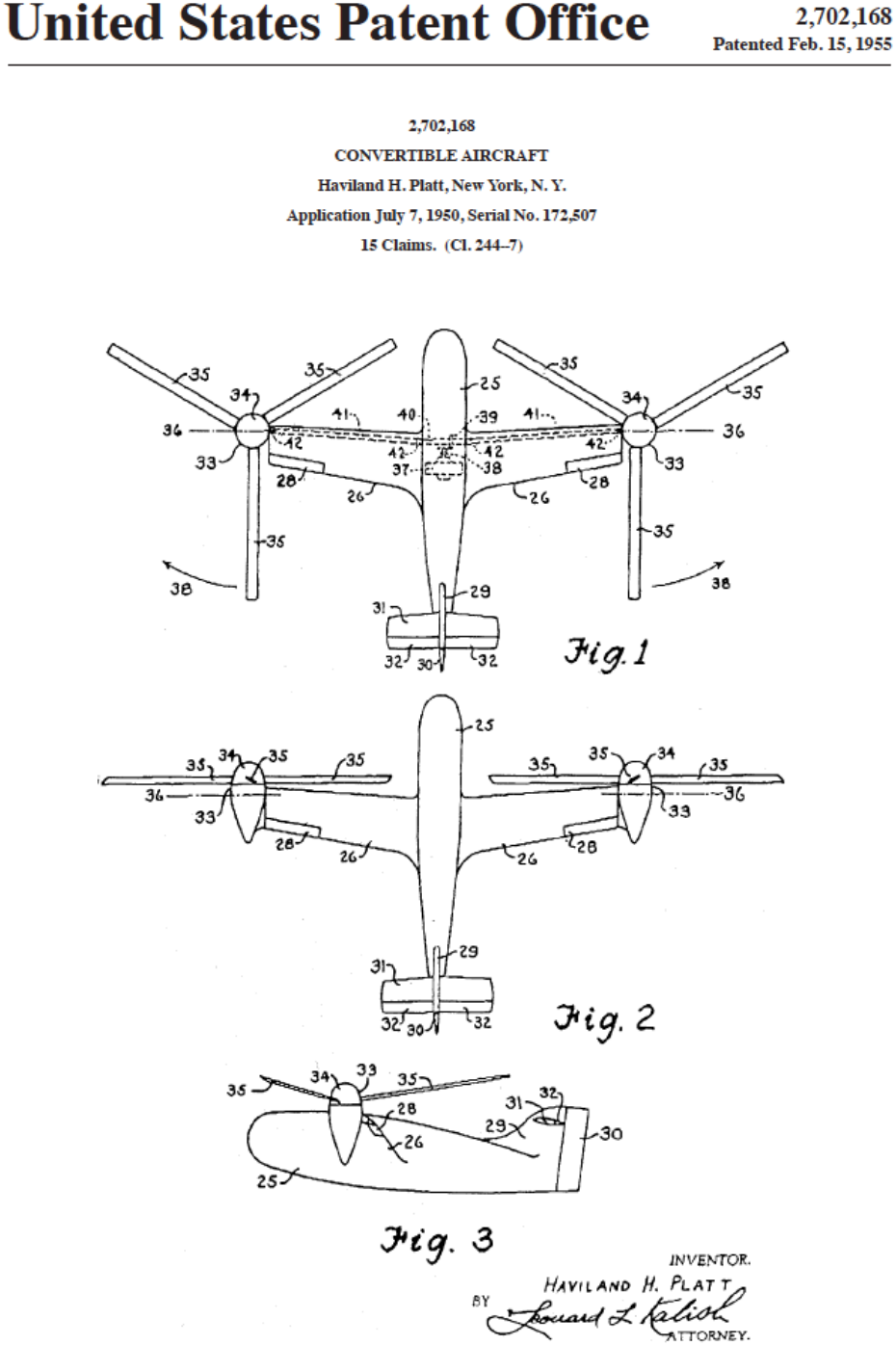
https://history.nasa.gov/monograph17.pdf

Introduction - Background

Illustration from the Haviland Platt patent of the tilt rotor concept.
United States Patent Office 2,702,168

Patented Feb. 15, 1955

CONVERTIBLE AIRCRAFT
Haviland H. Platt, New York, N. Y.
Application July 7, 1950, Serial No. 172,507
15 Claims. (Cl. 244--7)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CONVERTIBLE AIRCRAFT
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Application July 7, 1950, Serial No. 172,507
15 Claims. (Cl. 244–7)

Fig. 1

Fig. 2

Fig. 3

INVENTOR.
HAVILAND H. PLATT
BY Howard L Katich
ATTORNEY.

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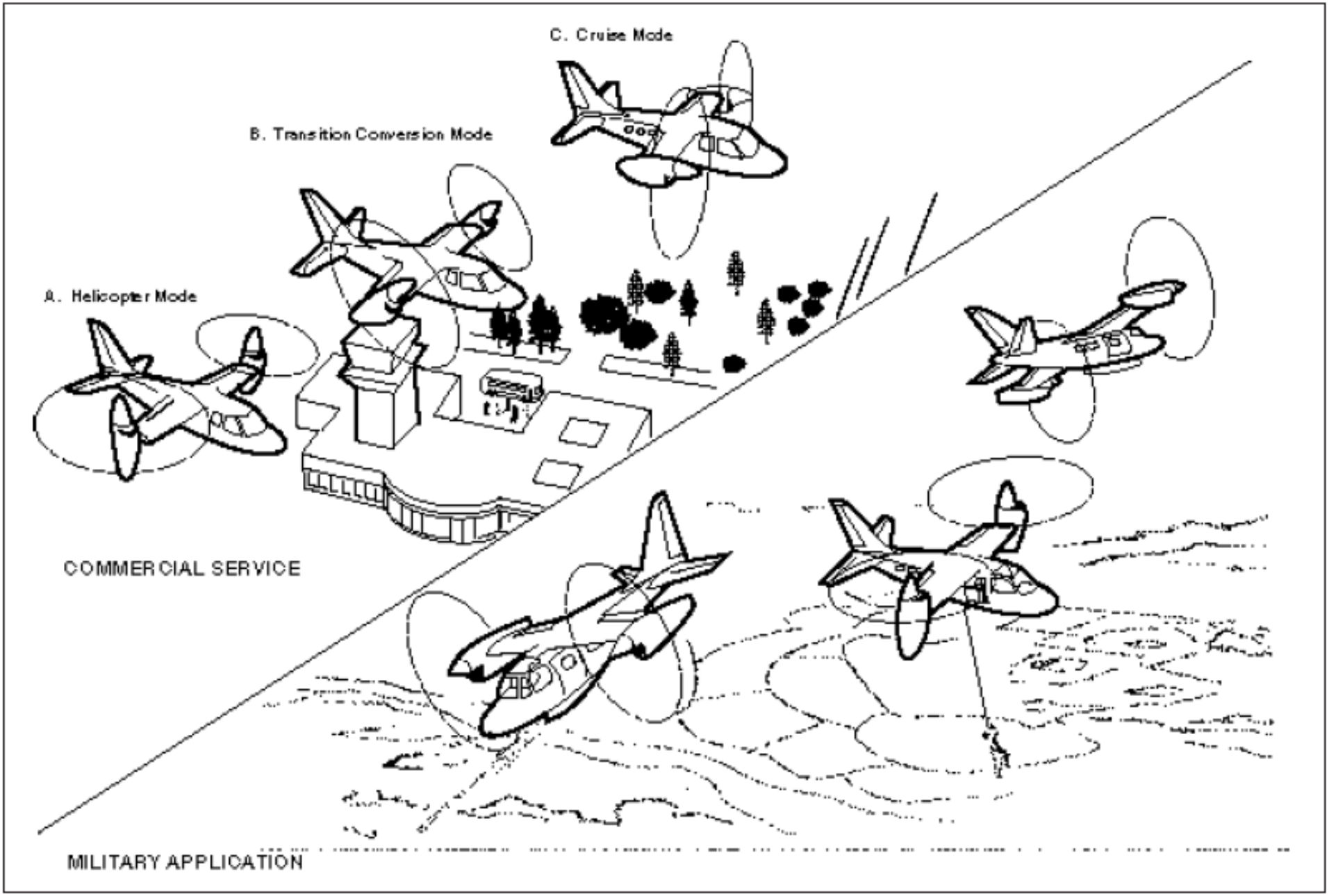
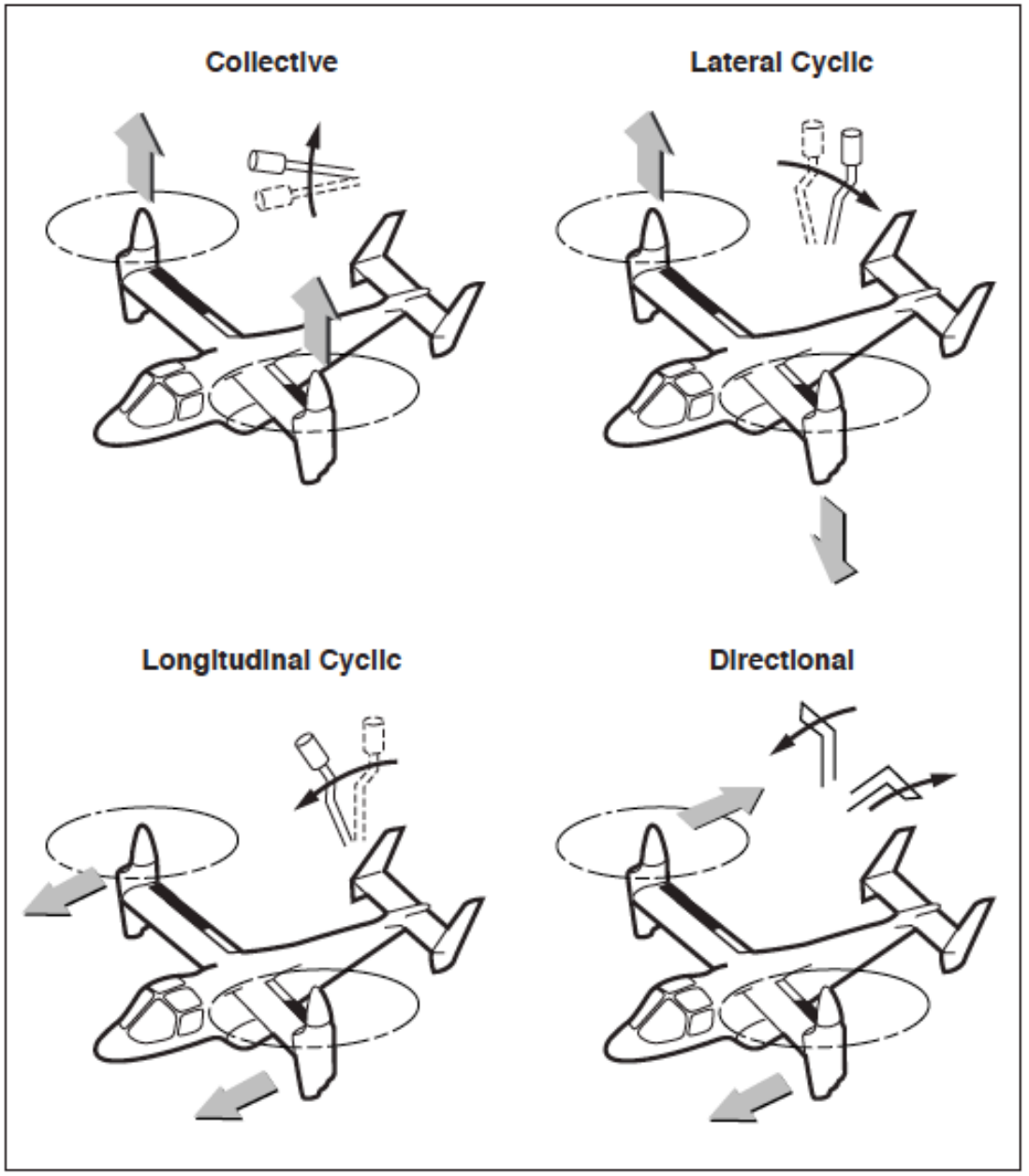
Introduction - Background



https://history.nasa.gov/monograph17.pdf Illustration from 1974 Tilt Rotor Research Aircraft - Project Plan

Introduction - Background

XV-15 during short takeoff performance test.
(Ames Photograph AC82-0723-22)



Proprotor response to cockpit control input.

https://history.nasa.gov/monograph17.pdf

Introduction - Background

Joby's wild 16-rotor convertible aircraft for long-range, high-speed, electric VTOL commuting

Loz Blain | December 1st, 2015

Joby conceives the S2 VTOL tilt-rotor aircraft as a kind of commuter aircraft (Credit: Joby Aviation)

https://www.youtube.com/watch?v=AYhs4OFEgDw

http://newatlas.com/joby-s2-tilt-rotor-vtol-multirotor-aircraft-concept/40662

Introduction

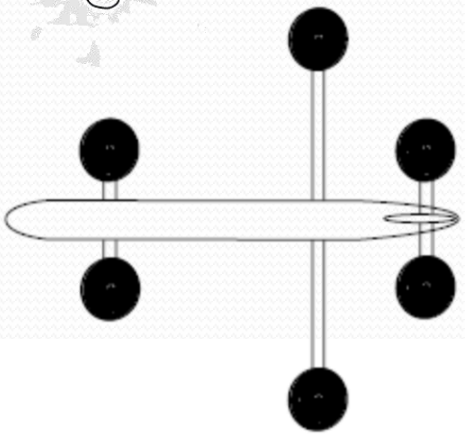
- Principle of convertible aircraft

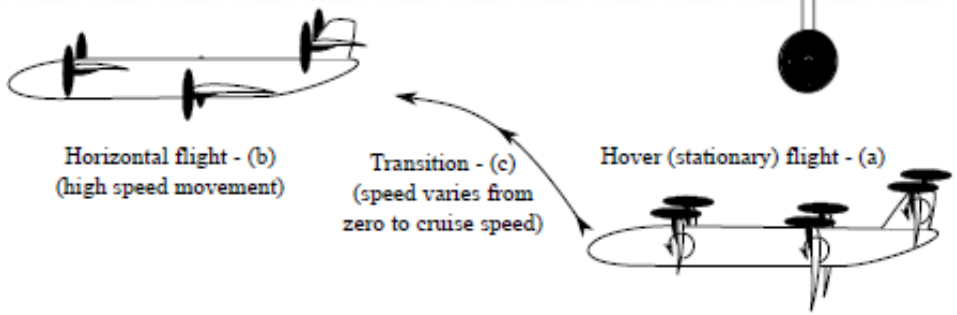
Cruise flight
(fast forward flight)

Transition
(horizontal speed varies from zero to cruise speed)

Stationary flight
(speed close to zero)

- Stationary flight behaviour similar to multi-copters:
  - Vertical take-off/landing (no need for dedicated runway)
  - Actuator redundancy (improved safety)
- Horizontal flight similar to conventional aircraft:
  - Fast forward flight speed
  - Reduced energy consumption
  - Improved autonomy





General objectives

- This project concerns the study of alternative transportation systems, based on the use of autonomous convertible aircraft, environment friendly and safe for people and habitations.

- Environment friendly:
  - Vertical take-off and landing ⇒ small footprint (no need for runways)
  - Electric engines ⇒ Zero emission / Low noise level
  - Wing profile optimized for cruise flight ⇒ energy optimization

- Safety:
  - Automated take-off, landing and transition procedures ⇒ reduction of risk related to human factor (80% cause of accidents):

Scientific and technological innovation

- Design of an intelligent autonomous control system (most importantly during take-off, landing and transition)
- Fault tolerant trajectory control despite actuator/sensor failures
  - Actuator/sensor redundancy (i.e. helices)
  - Last resort rescue trajectories ensuring safety for people and habitations

Scientific and technological workpackage

- Development of dynamic model:
  - Valid at low speed and during transitions from stationary to in cruise flight and vice versa
  - New (on-line) parameter identification algorithms

- Generate transition trajectories and fault tolerant robust tracking:
  - Fault detection and isolation (actuator/sensor/battery)
  - Path planning and safe landing trajectories in nominal and faulty case
  - Robust and fault tolerant transition control

Previous work (student projects)

- Concept Innovant Respectueux de l'Environnement à Motorisation Electrique (CIREME)
  - Proposed by a former Air France pilot
  - Objective: design and construction of the structure

- Tri-copter
  - In partnership with MAV Solutions
  - Objective: modelling and control, design of LIDAR sensor for obstacle avoidance

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Project tasks (first year)

- Task T1 (project coordination)
  - 5 advisory board meetings during the project
- Task T2 (experimental test-bench)
  - Industrial partner support for the construction of the convertible (technical specifications are being analysed)
- Task T3 (non-linear model of convertible)
  - Master student has been recruited (Gemma Prieto Aguilar) for 5 months (February 27th to July 28th)
  - Objective:
    - obtain the mathematical model of the convertible from the technical specifications given in T2
    - Build a Matlab/Simulink model
    - Study the flatness of the obtained model (initial work for T4 and T5)

Project tasks (second and third years)

- Task 3 – continuation
  - Second master student to work on the model identification from data
- Task 4 (fault detection & identification)
  - Propose algorithms to detect if a fault has occurred and to estimate its cause
- Task 5 (fault tolerant guidance)
  - Propose algorithms for piloting the convertible aircraft along a predefined trajectory in the presence of possible model uncertainties and system technical faults

Project funding

- Financing: ANR (French National Agency for Research)
- Starting date: December 1st, 2016
- Duration: 2 years (extendable to 3 years)
- Hosting institution: Univ. Bordeaux, IMS-lab
- This project is labelled: Aerospace Valley
- Total budget: 37,8 k€

Expected spin offs

- Take part in the introduction into civilian applications of a means of transportation with numerous advantages:
  - Energy saving (w.r.t. conventional multi-copters)
  - Reduced societal cost (low footprint)
  - Large choice of industrial applications due to the improved autonomy

Results valorisation and dissemination

- Participation at national and international conferences and journal publications
- Industrial partner support for the funding of a PhD thesis is welcome
- Fruitful partnership with the University of Cincinnati in UAV control

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Research team (University of Bordeaux, IMS-lab)

Tudor-Bogdan Airimitoaie (Assoc. Prof., project coordinator) : system identification and adaptive control.

Loïc Lavigne (Assoc. Prof.) : fault detection and diagnosis, path planning, flat systems and robust control dedicated to aeronautics and space domains.

Franck Cazaurang (Prof.) : path planning, fault tolerant guidance, dynamic inversion and robust control dedicated to aeronautics and space domains.

Christophe Farges (Assoc. Prof.) : fractional order models analysis and control, robust H_∞ control, fault detection.

Advisory board members

- **Kelly Cohen** (tenured Professor of Aerospace Engineering at the University of Cincinnati and Director of MOST-AERO) : intelligent systems, feedback control of large scale spatio-temporal dynamic systems, fuzzy logic control of earthquake resilient structures, low order modelling, non-linear system identification, and control of morphing tensegrity based structural systems.

- **Isabelle Fantoni** (CNRS researcher at the Heudiasyc lab in Compiègne, France) : nonlinear control for under-actuated mechanical systems by using approaches based on energy, passivity, Lyapunov theory, modelling and control of mini-aerial vehicles, use of vision for localization, navigation and control of drones, navigation assistance by optical flow.

- **Jean-Marc Grolleau** (Thales engineer and Director of the AETOS cluster) : development of autopilot, electric flight controls for the Airbus A340, military aircraft modernization, international purchases of military UAV systems.

Thank you!

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