The role of Universities in the future of Rotorcraft

Luigi Vigevano

Aerospace Science and Technology Dept. - Politecnico di Milano

2nd International Symposium on the Rotary Wing

A Flexible Answer to Complex Scenarios
Outline

1. From a recent past: 2012 CESMA Symposium
   *The future of Rotary Wing*

2. Present developments

3. Strategic programs in the U.S. and Europe

4. How Universities fit this scenario?
From 2012 CESMA Symposium on Rotary Wing

The objectives of the 2012 seminar are still valid:

- Examine the operational use of rotary wing aircraft
- Highlight the performance requirements for future rotary wing aircraft
- Identify critical technologies which need to be developed in order to satisfy such requirements.

Some conclusions were drawn regarding:

- requirements
- configurations
- economic scenario

- Reduced military helicopter market, while the civil market is showing some signs of growth
- Reduced funding to operate military forces: “austerity” climate
Requirements:

- **Performance**
  - increase speed, range, payload, fuel efficiency

- **Safety**
  - increase reliability, survivability, situation awareness
  - reduce pilot workload
  - increase DVE capability

- **Environment**
  - reduce noise, pollutant emissions

- **Operational capability**
  - provide seamless & quick aircraft integration

Configurations:

- **Helicopter**
- **Compound helicopter**
- **Tilt-rotor**
Present developments

- **Sikorsky X2/S-97 Raider** (225 kn)
- **Piasecki X-49A Speedhawk** (178 kn)
- **Airbus Helicopters X3** (255 kn)
- **AgustaWestland AW609** (330 kn)
Present developments: Bluecopter demonstrator

- Bluecopter → demonstrate “green” technologies in flight

- Objectives:
  - Significant reduction in CO₂ emission and fuel consumption up to 40%
  - Noise reduction of around 10 EPNdB below ICAO noise certification limits
  - Development of “transversal” technologies allowing for serial applications to all helicopter classes

- New blade design
- New Fenestron design
Present developments: Bluecopter demonstrator

- Hub and fuselage fairings

- Engine power management

- Achieved results:
  - 13% reduction in fuel consumption and an increase of 10 Knots in maximum forward flight speed
  - with power management a further reduction in fuel consumption up to 38%
  - approximately 8 EPNdB margin to the ICAO limits → best-in-world acoustic signature for approach conditions
Strategic programs in the U.S. - JMR

Future Vertical Lift (FVL) program → Joint Multi-Role (JMR) rotorcraft

- A family of helicopters for the United States Armed Forces. Variants of four different sizes will be developed:
  - light / medium / heavy / "ultra"

- Objective vehicle attributes:
  - Scalable common core architecture
  - Integrated aircraft survivability
  - Speed 170+ kts
  - Range 424 km (combat radius)
  - Performance at 6,000 feet and 95°F ("6k/95")
  - Shipboard Compatible
  - Fuel Efficient
  - Commonality
JMR program

- Phase 1 competition (October 2013, $6.5 million each)
  - Sikorsky-Boeing → SB-1 Defiant
  - Bell-Lockheed → V-280 Valor
  - AVX
  - Karem → TR36TD

- Downselection (August 2014): Sikorsky-Boeing & Bell-Lockheed were selected to build a technology demonstration aircraft with flight tests in 2017
DARPA VTOL X-plane:

- Objective: to fly faster than conventional rotorcraft without compromising hovering efficiency or range
- Unmanned prototypes

- Rotor blown wing (Sikorsky and Lockheed Martin) → tailsitter
DARPA VTOL X-plane

- **LightningStrike**
  (Aurora Flight Sciences)

- **TR36XP tiltrotor**
  (Karem Aircraft)

- **PhantomSwift**
  (Boeing)
Other projects

- Other Boeing’s projects:
  
  Unloaded Lift Offset Rotor – ULOR (increased range, \( V > 250 \) kn)

  DARPA Mission Adaptive Rotor (smart rotor)

  DARPA Disc Rotor (\( V = 350 \) kn)
Strategic programs in Europe: Clean Sky 2

- Key elements:
  - IADP (Innovative Aircraft Demonstration Planforms)
    → Large Passenger Aircraft
    → Regional Aircraft
    → Fast Rotorcraft
  - ITD (Integrated Technological Demonstrator): airframe, engine, systems

- Fast Rotorcraft IADP:
  - Tilt-Rotor demonstrator
  - Compound demonstrator
Clean Sky 2: Tilt-Rotor demonstrator

- Next generation because:
  - new architecture, STOL in airplane mode
  - extended range/payload vs. current T/R
  - forward speed close to turboprops
  - design tailored to various operations
  - competitive cost per seat mile
  - mission efficiency and productivity

- Based on AW *ERICA* design (NICETRIP EU project, 2007-2014)
Clean Sky 2 - Compound demonstrator: LifeRCraft

- Features and capabilities:
  - Fixed wing for energy efficient lift
  - Open propellers for energy efficient propulsion
  - Main rotor for energy efficient VTOL
  - Anti-torque & yaw control with propellers
  - Variable speed rotor and props
  - Typical operational speed 220 kts (410 km/h)
  - Fuel/CO$_2$ per km → 20 to 30% less than Y2010 helicopter

- Based on AH X3 design
The role of University

● Which role the Universities may have in this scenario?

● Education

- At DAER/PoliMI we started a Master Level program in Aeronautical Engineering with specialization in Rotary Wing Aircraft

First Year:
AERODYNAMICS OF HELICOPTERS
AEROSPACE STRUCTURES
FLIGHT DYNAMICS
DYNAMICS AND CONTROL OF AEROSPACE STRUCTURES AND FUNDAMENTALS OF AEROELASTICITY
COMPRESSIBLE FLUID DYNAMICS
FUNDAMENTALS OF THERMOCHEMICAL PROPULSION
NON-LINEAR ANALYSIS OF AEROSPACE STRUCTURES
HEAT TRANSFER AND THERMAL ANALYSIS
COMMUNICATIONS SKILLS

Second Year:
ROTORCRAFT DESIGN
MODELING AND SIMULATION OF AEROSPACE SYSTEMS
EXPERIMENTAL TECHNIQUES
ESTIMATION IN AEROSPACE MECHANICAL SYSTEMS RELIABILITY
DYNAMICS AND AEROELASTICITY OF ROTORS
ON BOARD SYSTEMS & INTEGRATION

● We encourage student teams to participate to intern. competitions
Student competitions

- **31th AHS Student Design Competition** (2013/14), with specifications issued by AW similar to those of the 1st phase of DARPA X-Plane design

- Graduate competition winner: **Georgia Tech XV-58**

- Third place: **Rensselaer Polytechnic Institute Emperor**
Student competitions

- Second place, and best first entry: **Politecnico di Milano Compound Tilt Rotor**

![Diagram of Politecnico di Milano Compound Tilt Rotor with labels for take off/hover, transition I, transition II, transition III, and cruise.]

- Take off/hover
- Transition I
- Transition II
- Transition III
- Cruise

Flaperons to reduce blockage in hover

Folding blades

Tilting nacelle & Outer wing

Propellers
The role of University

● Research

- Strengthen **multidisciplinary** research
  → DAER Rotorcraft Research Labs (RRL)

Aerospace Systems & Control Lab (ASCL)

Aerospace MAterials & TECHnology Lab (AMATECH)

Crashworthiness Lab (CrashLab)

Structural Integrity Advanced Materials & Structures Lab (SIAMS)

Aeroelasticity & Vibroacoustics Lab (AVLab)

Fixed- and Rotary-wing Aircraft Multidisc. Engng (FRAMELab)

Rotorcraft Aerodynamics Lab (RAL)

Flight Mechanics & Flight Systems (FMSLab)
DAER Rotorcraft Research Labs

- AMATECH - Aerospace MAterials & TECHnology Lab

  - Composite Materials (Structural and Bio-based)

  - Smart Structures
    - Health Monitoring
    - Actuation

  - Morphing Structures

  - Self-Healing Materials

- Physical tools in materials science
DAER Rotorcraft Research Labs

• ASCL - Aerospace Systems and Control Lab
  ▶ Identification for helicopter flight mechanics
  ▶ Active control of vibrations in helicopters
  ▶ Rotorcraft Flight Control System (FCS) design

• AVLab – Aeroelasticity and Vibroacoustic Lab
  ▶ Aeroelasticity & vibration control
  ▶ Acoustics
  ▶ Active control of structures
• CrashLab - Crashworthiness laboratory

► Cabin safety

► Bird impacts

► Material and component characterisation

► Ditching and fuel tank safety
DAER Rotorcraft Research Labs

- FMSLab - Flight Mechanics & Flight Systems
  - System Identification and Trajectory Optimization Program
  - Rotorcraft kinematic, dynamic and aeroelastic analysis
  - Rotorcraft UAVs
  - Hybrid-electric aircraft design
DAER Rotorcraft Research Labs

- **FRAME** – Fixed and Rotary-wing Aircraft Multidisciplinary Engineering Lab
  - Tiltorotor aeromechanics
  - Rotorcraft Pilot Couplings
  - Aeroservoleasticity with CFD
  - Ice accretion
  - Robust shape optimization for rotorcraft and morphing airfoils
DAER Rotorcraft Research Labs

- RAL - Rotorcraft Aerodynamics Lab
  - CFD for rotorcraft aerodynamics
  - Model rotor tests
  - Dynamic stall & Gurney flap
  - Tilt-rotor aerodynamics
- SIAMS: Structural Integrity of Advanced Materials & Structures Lab

- Development of constitutive law

- Damage tolerance of composite elements

- Delamination

- Multi-scale approaches to ceramic matrix composites

- T-Joints
The role of University: recommendations

- How University Education & Research can be effective for the rotorcraft world?

- Several aspects that hamper this effectiveness:
  - present EU policy of research funding
  - shortage of National funding, both from *Industry* and *Public Administration*
  - lack of National strategic programs

- Policies of mutual collaboration:
  - increase National cooperation to put forward EU funded project proposals
  - promote a *culture of research* within the Industrial Partners
  - carefully select the research subjects to be pursued
    → to be balanced among different TRLs
  - make effective use of “small amounts” of funding
    → as an example, sponsor PhD scholarships on dedicated projects
Thank you for your attention

Questions?

http://www.aero.polimi.it
luigi.vigevano@polimi.it