“Rotorcraft – Back to the Future”
A Discussion of the Past, Present, and Future of Rotorcraft

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Technical University of Munich
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V/STOL Aircraft and Propulsion Concepts

- We have done it all before

- Except for helicopters, only a handful of V/STOL concepts have reached production
Competition Decreasing -- Derivative Modifications Increasing

**New Starts**

- **1960s**
  - CH-46D/F
  - CH-47B/C
  - CH-53D
- **1970s**
  - CH-46E
  - CH-53E
  - CH-47D
- **1980s**
  - OH-58D
  - UH-60L
  - MH-47E
  - MH-60K
- **1990s**
  - CH-47F
  - UH-1Y
  - AH-1Z
  - AH-64D
- **2000s**
  - VH-71A
  - ARH-70A
  - UH-72
  - MH-47G
  - AH-64B 3
  - UH-60M
  - CH-53K
  - CSAR-X

**Impact of increasing cost and complexity**

**Impact of budget constraints**

- **COTS**
  - Commercial Off-The-Shelf
- *****
  - Technology Demonstrator or Prototype

Program Cancelled
# U.S. Jet Fighter vs. Rotorcraft Generations

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- **1st Gen Rotorcraft**
  - Subsonic
  - Guns
  - No radar

- **2nd Gen Rotorcraft**
  - Supersonic
  - Radar
  - Air-air missiles

- **3rd Gen Rotorcraft**
  - Maneuverability
  - Adv. weapons integration
  - Survivability
  - Look down, shoot down capability

- **4th Gen Fighters**
  - Stealth
  - Fly-by-wire
  - Net centric
  - Thrust vectoring

- **5th Gen Fighters**
  - Higher speed
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  - Signature reduction
  - Vc > 170 kts

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50 Years of DoD Aviation Investment
1960 – 2010

RDT&E

$321 B
(FY 2011 $)

Procurement

$926 B
(FY 2011 $)

83% / 17% investment split between fixed- and rotary-wing
US Army Aviation S&T Investment

Constant 2008 Dollars (Millions)

Technology Readiness Level (TRL) = 1 to 4

Downward trend in DoD rotorcraft investment over past 20 years!
A Look at Today
There hasn’t been this much excitement in the rotorcraft industry since the 1960’s

Piasecki X-49A SpeedHawk (2007)

Eurocopter X3 (2010)

Sikorsky X2 Technology Demonstrator (2008)

Boeing/DARPA Disc Rotor
Have we made progress?
Co-Axial Compound Helicopters

Sikorsky Light Anti-Submarine Attack Vehicle – LAAV Concept (1968)

Sikorsky XH-59A Advancing Blade Concept (ABC™) (1975)

Sikorsky LHX Concept (1982)

Sikorsky X2 Technology Demonstrator (2008)
Have we made progress?
Single Rotor Compound Helicopters

Bell UH-1 Model 533 HPH III – 274.6 knots (316.0 mph) (1969)

Eurocopter X3 – 180 knots (207 mph) (2010)
Have we made progress?
Piasecki Compound Helicopters with the Vectored Thrust Ducted Propeller

Piasecki 16H-1 Pathfinder (1962)

Piasecki 16H-1A Pathfinder II (1966)

X-49A SpeedHawk (2007)
Have we made progress?
Compound Tandem Rotor Helicopters

Chinook Compound Concept (1961)

CH-46 Tandem Wing Compound (mid-1960s)

Unloaded Lift Offset Rotor – ULOR (Ongoing Design Project)

Model 347 Tandem Compound (early 1970s)
Have we made progress?

Disc Rotors

Jacob Ellehammer – first ‘Disc-Rotor Helicopter’ concept to fly (1912)

Ellehammer – Disc-Rotor wind tunnel model and test (1935)

Jonathon Caldwell – ‘Disc-Rotor Plane’ (1934)

Boeing/DARPA Disc Rotor (Ongoing Design Project)

SOURCE: 100 YEARS OF DISC-ROTOR RESEARCH - A BRIEF HISTORY, ANGELO N. COLLINS and MICHAEL J. HIRSCHBERG, Presented at the International Powered Lift Conference, October 5-7, 2010, Philadelphia, PA
Have we made progress?

Tilt Rotors

Baynes “Heliplane” (1938)

Platt-LePage Tilt Rotor Design (1940s)

Transcendental Model 1-G (1954)

Bell XV-3 (1955)

Transcendental Model 2 (1957)

Bell XV-15 (1977)

USMC/Bell Boeing MV-22B Osprey (1989)

In production and operational with the U.S. Marine Corps and U.S. Air Force, the V-22 recently surpassed 100,000 flight hours!
What is going on?

“Recent” Technology Advancements

- For the most part, it is not the configurations that are advancing .... it’s the Technology Enablers

What technology breakthroughs have been demonstrated in this decade?
A generational leap desired in range \textit{and} speed – all at 6,000 ft/95°F
Joint Multi-Role (JMR) Program

(continued)

Maximize commonality to improve affordability

JMR program appears to be the future of DoD Vertical Lift
Back to the Future – Prototyping [e.g. Opportunity]

Model 347 ➔ Fly-by-Wire

XH-59A ➔ Advancing Blade Concept

X2 ➔ Speed, maneuverability

XV-15 ➔ V-22

Model 360 ➔ V-22 composite airframe

X-49A ➔ Speed

ARTI ➔ RAH-66

S-76B Fantail ➔ RAH-66 anti-torque system

X3 ➔ Speed
Hurdles

- Existing fleet modernization programs:
  - Bell Boeing V-22 Osprey
  - Boeing AH-64D Apache
  - Boeing CH-47F Chinook
  - Sikorsky UH-60M Black Hawk

- Fixed-wing emphasis
- Customers collaboration
- International competition
- Possible loss of critical skills

The US Industry Faces a Precarious Future

![Graph showing rotorcraft deliveries from CY08 to CY26](source: Boeing analysis of PB09)
Exciting projects are already under-way

Unloaded Lift Offset Rotor – ULOR

DARPA Mission Adaptive Rotor – MAR

DARPA Disc Rotor
ULOR Configuration Features

Unloaded Lift Offset Rotor – ULOR

- Same payload as H-47 with greater range
- High speed cruise > 250 knots
- More maneuverable than H-47
- Advanced 4-bladed rotor 60 ft [18.29m] diameter
- Underfloor fuel (2,000 gal 7570.8 liters) in crashworthy cells
- 8-ft (2.44m) diameter propellers
- Retractable landing gear
- Similar external dimensions as H-47
- Same internal cabin dimensions as H-47

30 ft 2 in. [9.19m] Length X 6 ft 6 in. [1.98m] Height
X 7 ft 6 in. [2.29m] Width

ULOR Mission Scenario
Boeing/DARPA
Edgewise Mission Adaptive Rotor (eMAR)

Features on a Notional New Design Rotorcraft

- Variable rotor speed
- Swashplateless rotor system
- Active blade twist
- Active leading edge
- Active trailing edge
- Active tip sails
DARPA/Boeing/VPI
Disc Rotor Concept Study

- High-speed VTOL/troop assault
- (2) turboshaft engines or turboshaft/turbofan combination
- Unique 350+ knots speed capability
What will next generation rotorcraft look like?

- Active drag reduction
- Mission Adaptive Rotor technologies
- Ultra-low vibration and noise
- Adaptive self-healing structures
- Next generation digital flight controls
- Single-pilot crew station
- Advanced engine and hybrid propulsion technologies
- Morphing wings
- Next generation advanced NOTAR

Technology Demonstrators and Prototypes have worked very well in the past...
Parting Comments
Questions?

Thank you.