TOWARDS DESIGNING HIGH ASPECT RATIO HIGH ALTITUDE JOINED-WING SENSOR-CRAFT (HALE-UAV)

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See also ADM001685, CSP 02-5078, Proceedings for Aerodynamic Issues of Unmanned Air Vehicles (UAV)., The original document contains color images.
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• Lastly, any opinions expressed are those of the author.
This Presentation

• Introduce HALE-UAV
• A Vision of Future – Sensor Craft Importance
• Joined-Wing Configs.
• 2-D Laminar Aerofoils
• Aspects of 3-D Design, different Swept Tips
• LE Suction Control, Elliptic loadings, Neutral Stab.
• CFD Checks
• Inverse 3-D Design Capabilities
• Intake Design – Preliminary Work
• Avenues for Further Work
Typical HALE Global Hawk

span: 116 ft, length 44 ft
light composites, aluminium fuselage, COST $10M

Range 12000 nm, AUW 25,600 lb, range up to 2000nm at 65000ft
flies to an area 1200 miles and remains on station 24 hrs

cloud penetrating synthetic aperture radar /
ground moving target indicator, electro-optical and infra-red sensors

image an area 40,000 square miles (State of Illinois) in 24 hours
Bending Moments acting on an Inboard-Jointed Joined Wing.
Weight of Lifting Surfaces of Turboprop Transports Versus Aspect Ratio

extrapolate

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<tr>
<td>F</td>
<td>R</td>
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<td>(\Gamma^*)</td>
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<td>(\Lambda^*)</td>
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Effect of Sweep on Relative Weight of Lifting Surfaces of Turboprop Transport

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<tr>
<td>$\delta_{RF}$</td>
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<td>$\lambda$</td>
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<tr>
<td>$\Gamma^\circ$</td>
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Guess!
Good efficiency!
TANKERS

TRANSPORTS

Joined-Wing Transport Concept Features A Refueling Boom On Each Wingtip And More Control Surfaces Than Conventional Aircraft
AC2ISR: What the Future Will Bring

SENSOR-CRAFT WORLD

Reduced Exposure:
- Higher Capacity Links
- Reachback

Distributed/ Collaborative Planning

Surveillance & Recce:
- Greater use of Space
- Greater use of UAVs

Smaller Footprint

Expeditionary Air Forces

Precision C2

Command Centers

C2:
- Shared Common Operating picture
- Reduced Footprint Command Centers

Shooters:
- Improved Stand-off-PGMs
- New UCAV Platforms

Right Info to the Right Warfighter at the Right Time for the Right Decision
Sensor Craft UAV as Element of Global Awareness/Global Engagement Vision

- Space Interoperability
- Space Assets
- Comm Node
- Support Jamming
- Airborne ISR “Sensor Craft”
- Mini/Micro UAVs
- SEAD
- Weapons
- Covert Penetrator Recce/Strike
- Unattended Ground Sensors
Other joined-wing possibilities
Mission profile and requirements

Mission Segments

1. Engine Start & Warm-up
2. Taxi
3. Takeoff
4. Climb & Accelerate to Cruise
5. Cruise out 3000
6. Loiter
7. Return Cruise
8. Descend
9. Loiter at Sea Level
10. Landing, Taxi, Shutdown

Cruise Radius: 3000 nm
Loiter: 65 Kft for 40 - 80 hr (at 3000 nm range)
Payload: 4000 lb
Field Length: 5350 ft over 50 ft Obstacle (SLS)
Control: 20 kt cross-wind on takeoff and landing

Flight duration 4-6 days
Implies a Wide Flight Envelope

W/S range of interest: 30 - 60
T/W range of interest: .30 -.50
Mach 0.6,
CL=1.59
Re=0.35 mil/ft

Mach 0.6,
CL=0.88
Re=0.4 mil/ft

Mach 0.2
CL=0.95
Re=1.4 mil/ft

Mach 0.15
CL=0.7
Re=1.1 mil/ft

LAND

TAKE-OFF

CRUISE
CL

CRUISE, Re=0.44 mil/ft

LANDING, Re=1.1 mil/ft

TAKE-OFF, Re=1.4 mil/ft

Mach no
Reference Configuration - Antenna Integration

Design Driver: Aero-Performance of Very Thick Airfoils

2-D Driver
High t/c
High L/D
Laminar Flow 50% c
Critical Mach at cruise
Low Re
19.6% t/c, Navier-Stokes Results at Re 1 million, Mach 0.01, Biber & Tilmann
2-D CALCULATIONS, INVISCID, MACH no VARIES from 0.0 to 0.6

t/c 16% uncambered

M = 0.0
M = 0.2
M = 0.4
M = 0.6

M = 0.0
M = 0.2
M = 0.4
M = 0.6

t/c 16% cambered

M = 0.0
M = 0.2
M = 0.4
M = 0.6
2-D CALCULATIONS, INVISCID, MACH no VARIES from 0.0 to 0.6

- t/c 19.6% uncambered

- t/c 19.6% cambered
SUMMARISING THE AEROFOIL PERFORMANCE, LAMINAR FLOW CAPABILITY Uncambered & Cambered
Reference Configuration

AR wet = 5.5
Span = 200 ft
Sweep = 35 deg
Identical frontal view

AT1

FT1

FT2

JOINED WING CONFIGURATIONS
Aerofoil Shapes

AT! CONFIGURATION
AT!, BASIC CHARACTERISTICS, Uncambered Aerofoils
Cp Distributions & Interference Effects On Spanwise Loadings
DESIGNED WING, Super-Critical Type Aerofoil, Twist & camber

Assume Zero Static Margin (Neutral Stability)
Respective Wing Settings Follow, Use Panel Method
Spanwise Loadings  AoA = 3.25, 4.25, 5.25
Cp Distbns.

AoA = 3.25, 4.25, 5.25
EULER CFD CHECK
Designed Case & Off-Design look for extreme gradients
Design AoA + 3 deg

Design AoA + 4 deg

NOTE
Panel, CL = 0.59

Euler, CL = 0.51
Euler, M=0.6, Design AoA + 0 deg, CL = 0.51, Upper Surface
Euler, M=0.6, Design AoA + 4 deg, CL = 1.08, Upper Surface
POWERFUL INVERSE METHOD, KNOWN Target Pressure Distbn. “Supplanted” on a GIVEN WING
FIG. 16 PROGRESSION OF CHORDWISE LOADINGS ON FRONT WING THROUGH 6 CYCLES
FIG. 18 COMPARING AEROFOIL SECTIONS ON FRONT WING AT START & AFTER 6 CYCLES
COMPARING AEROFOIL SECTIONS ON FRONT WING AT START & AFTER 6 CYCLES (WING AND TAIL BOTH MODELLED)
Laminar AT1
CL & Cm Reference & Control due to 0.5 deg setting angle changes
SPANWISE LOADINGS AT Mach 0.6, CL=0.72, 0.9, 1.07, 1.25, 1.43, 1.6
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES

CL=1.07

CL=1.25
Comparing uncambered & designed configs at same CL values

Possibly exceeding laminar limits at wing junction

CL = 1.43

CL = 1.6

Comparing uncambered & designed configs at same CL values
SPANWISE LOADINGS AT Mach 0.15, CL=0.63, 0.74, 0.94, 1.1, 1.26, 1.41
Cp Distributions. AT Mach 0.15, CL=0.63, 0.74, 0.94, 1.1, 1.26, 1.41
Forward Swept Tip FT1 Laminar
SPANWISE LOADINGS AT Mach 0.6, CL=0.72, 0.9, 1.07, 1.24, 1.43, 1.6
Comparing Uncambered & Designed Configs at Same CL Values
COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES

CL=1.24

CL=1.43
Possibly Exceeding Laminar limits at Wing Junction

COMPARING UNCAMBERED & DESIGNED CONFIGS AT SAME CL VALUES

CL=1.6
Twin Fuselage intakes

Propulsion Considerations
Central Fuselage intake
COMPLEXITY

ORDER OF COMPLEXITY

Configuration

engine-face

Complexity Level

M, MFR variation

M, α & MFR

Geometry, M,
α, β & MFR

forward-swept corner

critical area (high suction)

Geometry, Scarf,
Installation
M, α, β & MFR
UNSCARFED INTAKES

Increasing MFR

\[ \text{MFR} = \frac{A_o}{A_c} \]

\( \alpha = 0^\circ \)

EFFECT OF MFR & \( \alpha \), ONSET OF EXTERNAL & INTERNAL LIP SEPARATION

Increasing MFR

stagnation at highlight

Higher \( \alpha \)

external separation

internal separation
UNSCRAFED, SCARFED & 3-D STEALTHY INTAKES
Central Intake Integration & Modelling
Central, MEF=0.6, M=0.5
Intakes, Propulsion

• Shown a Preliminary set of Results
• Sizing is the first Concern
• Altitude of Operation!
• Off-Design
• Suitable Power-plants!
• Possibly Two needed
• Work Continues ……
• Experimental Work needed
Configuration & Structure

• Configuration / Layout
• What Light Materials
• One or two Fuselage
• Are such high AR craft feasible, structure
• Aero-elastic tailoring
• Manufacturing Constraints
Aerodynamics / Flow Control / Control

- Viscous Effects: Laminar Flow Extent
- Spanwise press. gradients
- Effect of Sweep, lower sweep Config. !
- Field performance
- Off-design, side-slip
- Controls location, pitch, directional & lateral
- Off-design
- Flow control, what & where!
Experimental work

- Difficulty in modelling large AR Configs
- Reynolds Number Considerations
- Laminar flow in WT
- Half models
- Control effects not representative of full-scale
- A Radio Control Free-Flight Model
- Propulsion Integration Considerations
Concluding Remarks

• Introduced HALE - UAV
• A Vision of Future – Sensor Craft Importance
• Joined-Wing Configs.
• 2-D Laminar Aerofoils
• Different Type of Swept-Tips in 3-D
• Aspects of 3-D Design
• LE Suction Control, Elliptic loadings, Neutral Stab.
• CFD Checks – Forward-Swept Root area
• Inverse Design Capabilities
• Intake Design – Preliminary Work
• Avenues for Further Work
*** Thank You for Listening ***

So I hope, enough has been shown to interest and inform you in the fast moving field of Sensor-Craft
PLENTY of Further Work!

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Shall we try Comments and Questions?