High Altitude Long Endurance
UAV Configurations:

Civil UAV Applications & Economic Effectivity of Potential Configuration Solutions

- Giulio ROMEO, Politecnico Di Torino (Turin Polytec. Univ.), Dept. of Aerospace Eng., Italy.
- Zvi SHAVIT, Israel Aircraft Industries, Israel
- Zdobyslaw GORAJ, Warsaw Univ. of Technology, Dept. of Airplane & Helicopter Design, Poland
- Jean HERMETZ, Onera, France
- CIRA, DLR, UNINA
BIRD - Orbit: 570 Km
Spatial Resolution: 370 m
Repeat Cycle: 24 HOURS
Design Life: 5 years

LANDSAT - Orbit: 705Km
Spatial Resolution: 15-60m
Repeat Cycle: 14 days
Design Life: 5 years

Integration
SATellite + UAV =
Higher Resolution + Continuous Data

POLITO, DIASP, giulio.romeo@polito.it
# MAIN GOAL: to define and consolidate, within a 2 iteration design cycle, 3 HALE Configurations:

- MODULAR
- SOLAR
- BLENDED

# MULTI-DISCIPLINARY OPTIMISATION SOFTWARE developed to obtain the Optimised configuration

# FINAL CONFIGURATIONS: as result of best compromise among production cost, aerodynamic performance efficiency, structural efficiency and aeroelastic behaviour, propulsion efficiency, and safety.

# PERFORMANCE shall be improved by at least 20% with respect to current technologies.

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Design of 3 HALE UAVs

**MODULAR - IAI**

**SOLAR HALE - POLITO**

**BLENDED WING - ONERA**

**BLENDED WING - WUT**

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**SHAMPO Main Characteristics**

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Altitude</td>
<td>$Z$</td>
<td>17,000 m</td>
</tr>
<tr>
<td>Max. Power available for the Payload</td>
<td>$P_{PL}$</td>
<td>1300 W</td>
</tr>
<tr>
<td>Avionic Mass</td>
<td>$W_{AV}$</td>
<td>32.0 kg</td>
</tr>
<tr>
<td>Max. Payload Mass</td>
<td>$W_{PL}$</td>
<td>100 kg</td>
</tr>
<tr>
<td>Structural Mass</td>
<td>$W_{str}$</td>
<td>430 kg</td>
</tr>
<tr>
<td>Solar cells Mass</td>
<td>$W_{sc}$</td>
<td>127 kg</td>
</tr>
<tr>
<td>Take off Weight</td>
<td>$W_{to}$</td>
<td>924 kg</td>
</tr>
<tr>
<td>Power available for the Avionic</td>
<td>$P_{AV}$</td>
<td>325 W</td>
</tr>
<tr>
<td>Cruise Flight Power supplied to the electric motors</td>
<td>$P_{fly}$</td>
<td>6700 W</td>
</tr>
<tr>
<td>Sun Power (38°N April)</td>
<td>$P_{sun}$</td>
<td>11560 W</td>
</tr>
<tr>
<td>Efficiency Energy storage system (Fuel cell + al.)</td>
<td>$\eta_{FC}$</td>
<td>0.6</td>
</tr>
<tr>
<td>Density Energy storage system (Fuel cell + al.)</td>
<td>$W_{FC}$</td>
<td>550 Wh/kg</td>
</tr>
<tr>
<td>Efficiency Solar cells</td>
<td>$\eta_{SC}$</td>
<td>0.21</td>
</tr>
<tr>
<td>Density Solar cells</td>
<td>$W_{SC}$</td>
<td>0.6 Kg/m²</td>
</tr>
<tr>
<td>Efficiency Electric Motor</td>
<td>$\eta_{M}$</td>
<td>0.95</td>
</tr>
<tr>
<td>Efficiency Propeller</td>
<td>$\eta_{PROP}$</td>
<td>0.85</td>
</tr>
<tr>
<td>Number of Motors</td>
<td>$N$</td>
<td>8</td>
</tr>
<tr>
<td>Cruise Airspeed (TAS)</td>
<td>TAS</td>
<td>25 m/s</td>
</tr>
</tbody>
</table>

*SOLAR HALE UAV*

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SOLAR HALE UAV

Solar Cells

Fuel Cells

O2 / H2 Tanks

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EILAT, May 18-19th 2005
Development of Solar HALE-UAV

Introducing sweep angle to improve longitudinal stability

1st configuration

2nd configuration
Classical configuration to improve longitudinal stability

3rd configuration

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Solar HALE Wing Section

OUTER-Wing Section
DAE21 Airfoil

SH118 Airfoil

Aerodynamics

SOLAR HALE UAV

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Aerodynamic Results

**EFFICIENCY**

**ENDURANCE PARAMETER**

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Ailerons & Landing Gear

Ailerons actuators

Tricycle Landing Gear

SOLAR HALE UAV

aileron segments 1-2-3

Ailerons
Inboard section: 18.8m
Outboard section: 30.8m

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Flight Performance

**Longitudinal Static Stability**

<table>
<thead>
<tr>
<th>TAKEOFF</th>
<th>Ground roll</th>
</tr>
</thead>
<tbody>
<tr>
<td>V final</td>
<td>8.31 m/s</td>
</tr>
<tr>
<td>V initial</td>
<td>0 m/s</td>
</tr>
<tr>
<td>S Ground roll</td>
<td>138.77 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rotation</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>time to rotate</td>
<td>3</td>
</tr>
<tr>
<td>S Rotation</td>
<td>24.92 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>load factor</td>
<td>1.2</td>
</tr>
<tr>
<td>Radius</td>
<td>38.43 m</td>
</tr>
<tr>
<td>Vtr</td>
<td>8.68 m/s</td>
</tr>
<tr>
<td>Vclimb</td>
<td>9.06 m/s</td>
</tr>
<tr>
<td>Drag</td>
<td>272.2 N</td>
</tr>
<tr>
<td>Angle of climb</td>
<td>1.3 deg</td>
</tr>
<tr>
<td>Htr</td>
<td>0.010 m</td>
</tr>
<tr>
<td>S transition</td>
<td>0.9 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Take off &amp; Landing distances:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-off: 804m - Landing: 420m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ground roll</th>
</tr>
</thead>
<tbody>
<tr>
<td>V final</td>
</tr>
<tr>
<td>V initial</td>
</tr>
<tr>
<td>S Ground roll</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total length</th>
</tr>
</thead>
<tbody>
<tr>
<td>804.5 m</td>
</tr>
</tbody>
</table>

| S flare      | 2.1 m      |

<table>
<thead>
<tr>
<th>LANDING</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>V approach</td>
<td>9.8 m/s</td>
</tr>
<tr>
<td>h obstacle</td>
<td>15 m</td>
</tr>
<tr>
<td>Drag</td>
<td>455 N</td>
</tr>
<tr>
<td>gamma approach</td>
<td>2.8 deg</td>
</tr>
<tr>
<td>S approach</td>
<td>305 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flare</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>load factor</td>
<td>1.2</td>
</tr>
<tr>
<td>V td</td>
<td>8.7 m/s</td>
</tr>
<tr>
<td>Vflame</td>
<td>9.3 m/s</td>
</tr>
<tr>
<td>Radius</td>
<td>44 m</td>
</tr>
<tr>
<td>Hfl</td>
<td>0.053 m</td>
</tr>
<tr>
<td>S flare</td>
<td>2.1 m</td>
</tr>
</tbody>
</table>

**SOLAR HALE UAV**

**Lateral Static Stability**

\[
C_{n\beta} = 0.012 \\
C_{l\beta} = -0.083
\]
Within the MIL-F-8785C flying qualities levels criteria for a small light Aircraft in cruise condition (Cat B)

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Leading edge wing-box

<table>
<thead>
<tr>
<th>Weights</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing Skin</td>
<td>47 kg</td>
</tr>
<tr>
<td>Wing Ribs</td>
<td>36 kg</td>
</tr>
<tr>
<td>Wing Box</td>
<td>258 kg</td>
</tr>
<tr>
<td>Pay-load</td>
<td>100 kg</td>
</tr>
<tr>
<td>Avionic</td>
<td>33 kg</td>
</tr>
<tr>
<td>Pins</td>
<td>0.93 kg</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>890 kg</strong></td>
</tr>
<tr>
<td>Structural Weight</td>
<td><strong>382 kg</strong></td>
</tr>
</tbody>
</table>
EILAT, May 18-19th 2005
Structural design & analysis

Maximum wing deflection: 5.89m
Load factor = 4.5

Maximum fuselage deflection: 29mm
Load factor = 4.5

SOLAR HALE UAV

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Non-linear effect due to high-aspect ratio structure is not included in a 1st attempt. No critical speed detected up to 100m/s (at 17000m). Normative requirement fulfilled.

Tuzcu & Meirovitch, Virginia Polytechnic Institute 2003
The platform has to have a very long endurance of flight (4-5,000h) is supposed to fly continuously without failure. The loss of a platform must not cause damage to the service. Catastrophic failure conditions must be extremely improbable, i.e.:

The probability that a failure condition would occur maybe assessed on the order of $10^{-9}$ or less.

“The safety standard that should be maintained is one in which UAVs are operated as safely as manned aircraft, insofar as they should not present or create a hazard to persons or properties in the air or on the ground greater than that created by manned aircraft conducting similar operations” (FAA Advisory Circular 8/5/96).

A MTBF=40,000h for each motor and a MTBF=100,000h for each propeller is assumed for the reliability analysis obtaining a 0.991.

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EXTERNAL VIEW

Moving surface (control)

Trim elevator

Spoilers

SATCOM and LOS antennas

Sensors bay

FJ 44 2E engines

MTOW: 5400 kg
Payload: 610 kg
External & internal views

Max. fuel capacity: 2800 kg

Sensors fairings

BLENDED HALE UAV (ONERA)

Reference area: 51.3 m²
Aspect ratio: 18
Wing loading: 105.3 kg/m²
Max LD ratio (M=0.6): 32
MMO: 0.636
**Performance & Flying qualities**

**Main performance (ONERA & IAI)**
- Initial climb altitude: 50,000 ft, achieved in 20 min
- Hold: 1 h at 10,000 ft
- Loiter: 24 h at 60,000 ft
- Loiter alt. reached during cruise segment (climbing cruise)
- Overall fuel consumption: 2628 kg
- Service ceiling reached in 1h33
- Overall mission duration: 29 h
- Take off distance: 542 m (obs. 35 ft)
- BFL: 655 m
- Landing distance: 610 m
- Best RoC at SL: 28 m/s (at 138 m/s TAS)
Flying qualities (ONERA & WUT)

- Computation of short period, dutch roll, phygoïd and spiral motions
- Vehicle doesn’t satisfy requirements for Dutch roll mode
  - OBW_2 fulfils FAR 25 and MIL-F-8785C at (level 3)
  - Does not fulfill FAR 23 and MIL-F-8785C at (level 2).
  - Cannot be human manned in a backup -> use of a robust automatic flight control
Objective: maximizing of the global aerodynamic efficiency in loiter conditions

Airfoils design drivers: low nosed-up or zero moment coefficient

Geometric constraints for central part

Two ONERA specific airfoils: HOAT 192 (central part) and HOAT 140 (outer wing)

An optimized twist distribution
Safety & Reliability

- Based on systems block diagrams and unit reliability of equipment/components
- Systems block diagrams using parallel and serie architectures

MTBCF ~ 741 hr
MTBL ~ 51 500 hr
MTBUCL 515 000 hr
EILAT, May 18-19th 2005

Structural design & analysis

- Loads compliant with CS-23 (gust and manoeuvres)
- Wing torque box with 3 I-beam spars
- Carbon-epoxy composite materials
- First sizing:
  - Usual safety factor (1.5) applied
  - Sizing with bending limits about 16% of the semi wing span (at the tip chord) for 3.2g
  - Verification of stress limits at 4.8 g
A concept for which the two cycles analysis done gives confidence in its ability to fulfil requirements and missions specifications (500 kg during 24 h at 60 kft and 1000 km egress bound).

This concept demonstrates the potential of blended wing configuration.

Analysis also points out the high sensibility of Blended Wing UAVs to several aspects, mainly:

- flutter risks which require a deeper analysis
- the rather poor stability of such a vehicle that could lead to the use of robust automatic flight control system
Flying wing
Overall AR: 17.7
MTOW: 6350 kg
Wing area: 44.4 m²
Wetted area: 119.7 m²
Wing loading: 143 kg/m²
Engines: 2xWilliams FJ44-3, FJ44-4 in the future
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Main Sensors

EO/IR sensor
SATCOM antenna
Electronic racks

BLENDED HALE UAV (WUT)

Synthetic Aperture Radar

Navigation system
Parachute recovery system
Fly-by-wire or classical configuration?

To reduce instability at the CG fixed one had to move the foreplane back.

Arm of CANARD versus $S_C$ & $a_1$

- $S_C=2.16; a_1=0.07$
- $S_C=1.50; a_1=0.10$
- $S_C=4.50; a_1=0.10$
- $S_C=2.16; a_1=0.09$
- $S_C=2.16; a_1=0.10$

Classical tailplane

BLENDED HALE UAV (WUT)
Modification to improve longitudinal stability

Further modification to improve longitudinal stability

Modification to improve lateral stability
LRT-17.5: $(t/c)_{\text{max}} = 17.5\%$, $M_{\text{des}} = 0.62$

$Re_{\text{des}} = 1.5 \times 10^6$, $C_{l_{\text{des}}} = 1.18$
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Flaps, spoilers, elevons

BLENDED HALE UAV (WUT)
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Longitudinal trimming

\[ \delta_{\text{elevon}} = 0^\circ \]

\[ \delta_{\text{elevon}} = -10^\circ \]

\[ \delta_{\text{elevon}} = -11^\circ \]

\[ \delta_{\text{elevon}} = 8^\circ \]

\[ \delta_{\text{elevon}} = -15^\circ \]

PW-114;  \( H=19.5 \text{ km};\  \text{Ma}=0.6 \)

BEGINNING OF THE PATROL

END OF THE PATROL

BLENDED HALE UAV (WUT)
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Fuel system

**BLENDED HALE UAV (WUT)**

<table>
<thead>
<tr>
<th>Tank</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2000 l</td>
</tr>
<tr>
<td>II</td>
<td>1500 l</td>
</tr>
<tr>
<td>III</td>
<td>1400 l</td>
</tr>
<tr>
<td>IV</td>
<td>700 l</td>
</tr>
</tbody>
</table>

$\Sigma=5600\ l = 4200\ kg$

Order of empting: I, IV, II, III
Wing – torque box

Carbon rowing

Sandwich cover

BLEDENED HALE UAV (WUT)
EILAT, May 18-19th 2005

**Torsion box section**

<table>
<thead>
<tr>
<th>Mass [kg]</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>m₁</td>
<td>0.60</td>
</tr>
<tr>
<td>m₂</td>
<td>3.17</td>
</tr>
<tr>
<td>m₃</td>
<td>3.17</td>
</tr>
<tr>
<td>m₄</td>
<td>0.59</td>
</tr>
<tr>
<td>m₅</td>
<td>0.87</td>
</tr>
<tr>
<td>m₆</td>
<td>0.88</td>
</tr>
<tr>
<td>Torsion box total</td>
<td>9.28</td>
</tr>
</tbody>
</table>

Weights of wing components

<table>
<thead>
<tr>
<th></th>
<th>[kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>torsion box with fuel ribs, nose and anti-icing installation</td>
<td>96</td>
</tr>
<tr>
<td>control surfaces</td>
<td>11.5</td>
</tr>
<tr>
<td>wingtip with brackets</td>
<td>7.8</td>
</tr>
<tr>
<td>control surfaces’ consoles</td>
<td>3</td>
</tr>
<tr>
<td>actuators</td>
<td>16.5</td>
</tr>
<tr>
<td>fuel installation</td>
<td>6</td>
</tr>
<tr>
<td><strong>Whole wing</strong></td>
<td>2x 140.8 = 281.6 kg ≈ 4.5 % of max TOW</td>
</tr>
</tbody>
</table>
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Structure of fuselage

BLENDED HALE UAV (WUT)
Location and attachment

- Compact design
- Small interference drag
- Small assembly weight
- High efficiency of straight intakes
- Easy access & simply maintenance

BLENDED HALE UAV (WUT)
EILAT, May 18-19th 2005
PW114 main systems

PW114 main systems

BLENDED HALE
UAV (WUT)
Symmetric mode, fuel in wing only

\[ V_{kr} = 100 \text{ m/s} \]
## Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>GH</th>
<th>PW-114</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing span [m]</td>
<td>35,4</td>
<td>28</td>
</tr>
<tr>
<td>Wing area [m²]</td>
<td>50,2</td>
<td>44,4</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>25,1</td>
<td>17,7</td>
</tr>
<tr>
<td>Empty weight [kg]</td>
<td>4177</td>
<td>2200</td>
</tr>
<tr>
<td>Payload [kg]</td>
<td>1000</td>
<td>700</td>
</tr>
<tr>
<td>Fuel weight [kg]</td>
<td>6583</td>
<td>4150</td>
</tr>
<tr>
<td>Take-off weight [kg]</td>
<td>11622</td>
<td>6350</td>
</tr>
<tr>
<td>Take-off thrust [kN]</td>
<td>37</td>
<td>20,9</td>
</tr>
<tr>
<td>Wing loading [kg/m²]</td>
<td>231,5</td>
<td>143</td>
</tr>
<tr>
<td>Thrust loading [kg/kN]</td>
<td>314,1</td>
<td>304,1</td>
</tr>
<tr>
<td>Payload/wing area [kg/m²]</td>
<td>19,9</td>
<td>15,8</td>
</tr>
<tr>
<td>Payload/take-off thrust [kg/kN]</td>
<td>27</td>
<td>33,5</td>
</tr>
<tr>
<td>Payload/empty weight [kg/kg]</td>
<td>0.24</td>
<td>0.32</td>
</tr>
</tbody>
</table>
HALE modular, W=6000 kg
CL=1.1, CD=0.0359, K=31.25

PW-113, W_H=4350 kg
CL=0.8, CD=0.0270, K=29.6 (H=15km)

BLENDED HALE UAV (WUT)
A Multi-Role High-Altitude Long-Endurance Aircraft for Civil and Para-military Missions

- Modular twin jet aircraft concept *(2 engines to improve reliability)*
- Mission endurance --> 24 hr at 1000km range
- 500 kg interchangeable payload bay *(The modular concept)*
- Payload power 8kW MAX
- 65000 ft MAX ceiling altitude
- MAX Cruise speed 0.65 MACH at 60kft
EILAT, May 18-19th 2005

Configuration Features

Advanced composite material design

2XFJ44 class power plants

Satellite communication

Modular payload bay

Wing mounted landing gear bay

Advanced aerodynamics design
### Performance requirements (Starting point)

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Starting Value</th>
<th>Current Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Empty Weight</td>
<td>~3400 kg</td>
<td>~2010 kg</td>
</tr>
<tr>
<td>2</td>
<td>Payloads Weight</td>
<td>500 kg</td>
<td>500 kg</td>
</tr>
<tr>
<td>3</td>
<td>Fuel Weight</td>
<td>3400 kg</td>
<td>3480 kg</td>
</tr>
<tr>
<td>4</td>
<td>Take-off Weight</td>
<td>7700 kg</td>
<td>6000 kg</td>
</tr>
<tr>
<td>5</td>
<td>Ceiling</td>
<td>66 kft</td>
<td>66 kft</td>
</tr>
<tr>
<td>6</td>
<td>Endurance</td>
<td>24 hr</td>
<td>24 hr</td>
</tr>
<tr>
<td>7</td>
<td>Mission Altitude</td>
<td>55-66 kft</td>
<td>55-66 kft</td>
</tr>
<tr>
<td>8</td>
<td>R.O.C @ S.L. &gt;</td>
<td>2000 ft/min</td>
<td>3200 ft/min</td>
</tr>
<tr>
<td>9</td>
<td>Max Airspeed</td>
<td>340 ktas</td>
<td>340 ktas</td>
</tr>
<tr>
<td>10</td>
<td>Take-off Ground Roll</td>
<td>2000 m</td>
<td>1100 m</td>
</tr>
</tbody>
</table>

**MODULAR HALE UAV (IAI)**
Reducing the transportability Footprint to one standard 40ft (11.7m) container

Unitized structure (maximum segment length 11.7m)
EILAT, May 18-19th 2005

Aerodynamic analysis

By WUT

Meshed body:
7386 body panels

Modular HALE UAV (IAI)
The spars are comprised of upper and lower flanges made of GR\EP plies and sandwich web made of Rohacell core and GR\EP plies.
FEM ANALYSIS BY POLITO

DISPLACEMENT RESULTS

WING BOX BUCKLING

MODULAR HALE UAV (IAI)
Autonomous Flight

The System Architecture shall enable:

- Automatic Take Off
- Automatic Landing
- Autonomous Navigation and Flight Path Execution.
  (Human Operators became mission level managers and not pilots)
- Continuous BIT for Failure Detection
- Automatic In-Flight Reconfiguration Capability
1. Satellite Communication (SATCOM) for mission and control
2. Line Of Sight Communication (LOS) for directional command and control

The Antenna’s pedestal will be stabilized, in order to continuously track the satellite, while the UAV is moving and maneuvering.
Typical SAR/MTI with EO/IR for sensor cross-cueing and multi sensor fusion

- Sensor Electronics Unit
- Receiver/Exciter/Controller
- Integrated Sensor Processor
- Transmitter
- Power Distribution Unit
- MTI Synthetic Aperture Radar
- EO/IR Sensor
- Command Data Link Antenna

of aerial surveying, mapping, border patrol, law enforcement and other missions.
Typical Cellular Communication Payload

- 40" KuBand Wideband SATCOM Antenna
- Electronics & Controllers Units
- Forward Cellular sword antenna
- Cellular Communication Package
- Command Data Link Antenna
- Aft Cellular sword antenna
- 12 Basic Radio (BR) Units, each BR unit can serve 50 customers
Light and low cost airframe structure

- Composite materials
- Unitized segments structure
- Low cost/weight processes
- LRI (Liquid Resin Infusion)

The production technologies should be aimed towards cost reduction in one hand and increased performance (reduced weight) on other hand, leading to improved effectiveness.
The aeroelastic issue is important, especially for our configuration:
- High aspect ratio
- Target to reduce structure weight in order to increase performance

An iterative design loop is needed, this loop includes:
- Aircraft structure
- Aerodynamic
- Flight control
- Aeroelasticity.

The flight control solution to rigid body is not adequate here, and also if the flutter analyses show that the aircraft is free from dynamic aeroelastic instability within the flight envelope, we still have to design the flight control with interaction to aircraft structure, aerodynamic and aeroelasticity.
Aerodynamics

- Clean design
- Advanced laminar wing design

High altitude turbofan propulsion (modification of the FJ44-3 to high altitude)

- Lower SFC
- Noise reduction
- High reliability

Using the new/future 3500-pound thrust Williams FJ44-4 engine (modified to high altitude) with a continued infusion of improved technology, will give advantages in flight performance, especially in case of grows in takeoff weight.
Conclusion & Recommendations

- Concept of operation that will allow multi-mission/multiple payloads operation to reduce operation cost per hour => more sales.

- High reliable and durable systems – fail safe reliability concept, assuming that in case of failure the mission will be aborted (return home) if the next similar (like) failure may caused UAV Loss.

- Reducing maintenance requirements through system design
  - Selection of reliable and durable components
  - Selection of durable and corrosion resistant materials

- Maintenance concepts to reduce Mean Time To Repair (MTTR), Man Hours per Operating Hours (MMH/OH), crew, training, support equipment and spares.

*This reduction in maintenance requirements improves the UAV system Life Cycle Cost (LCC)*