Progettazione di veicoli aerospaziali

Unmanned Aerial Vehicle – UAV

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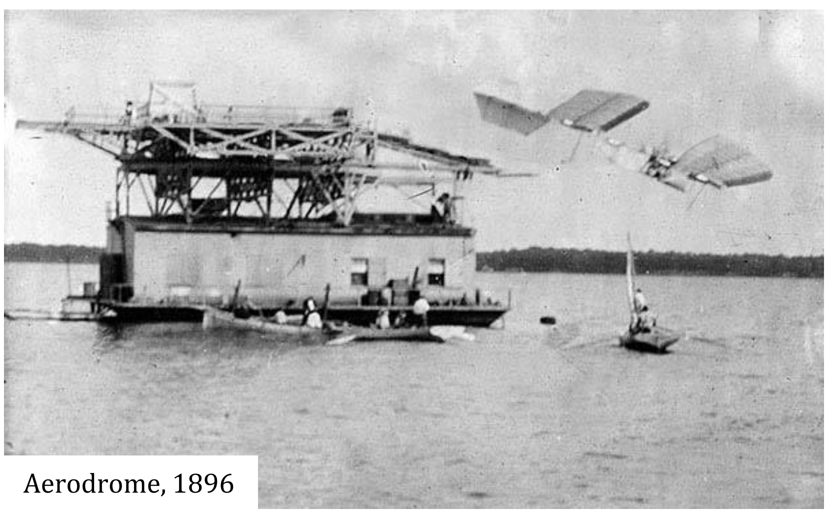
Definizione ed esempi

- Veicolo aereo motorizzato che non trasporta alcun operatore umano.
- Può essere autonomo o operato da remoto.
- Veicoli balistici, proiettili, torpedo, mine, satelliti e sensori *unattended* non sono considerati UAV.


Aerodrome, 1896

Leonardo Falco Xplorer, 2019

Manned vs Unmanned

- Missione ISR: intelligence, surveillance, and reconnaissance.
- Es. Cessna O-2 Skymaster.
- Peso componentistica: 600 lb vs 45 lb (270 kg vs 20 kg)

Component	Weight, lb	Notes
Pilot	160	Power for flight controls
Second crew member	160	Likely radio or ISR systems operator
Windows	20	Visibility for pilot and crew
Furnishings	60	Not ejection seats
Doors	30	
Instrumentation and avionics	100	Includes guidance and navigation equipment
Control interface	20	
Cabin environmental controls	30	
Survival kit	10	
Portion of electrical system	10	For powering avionics and cabin environmental controls

Component	Weight, lb	Notes
Autopilot and other avionics	15	
Flight control actuation	15	Electromechanical actuators
Line-of-sight communications	10	C2 and payload links
Portion of electrical system	5	Generator and power system

Attribute	Human Pilot	UAS Avionics
Acceleration limits	5–10 *g* peak	Design criteria. Some are designed to over 10,000-*g* shock.
Temperature limits	Body temperature must be maintained at 98.6 deg. Cabin temperatures typically 60 to 100°F.	Design criteria. Many avionics are designed to operate at −20 to 120°F.
Pressure limits	Typically 0.75–1 atm	Design criteria. Space electronics can operate in vacuum.
Orientation	Pilots are generally upright (sitting upright). Rare aircraft have prone pilot (lying down on belly with face forward)	Avionics and sensors can be designed for a wide range of orientations. Unmanned aircrafts can fly inverted for extended duration.
Mathematical operations	Humans have a limited ability to perform calculations in flight.	Avionics can perform millions of calculations per second, with an ever-increasing capability trend.
Upgradability	The Mark I human pilot capability experiences almost no change over relevant timescales. Variation exists in a population, but the distribution is nearly constant over time. Without controversial future biomechanical technology (i.e., cyborgs), pilots can't be upgraded.	Major revolutions in avionics and software occur about once a decade.
Reasoning	Pilots can flexibly react to unexpected situations. Pilot situational awareness is high due to visual cues, sounds, smell, and physical feel. Pilots have an intuitive feel for the aircraft sometime referred to as "seat of the pants."	Avionics can only react as programmed. Human operators in the ground stations can handle situations within the available interfaces if communications exist. The situational awareness of humans is limited to data received from the unmanned aircraft.
Visual sensor performance	The neck can enable a field of regard beyond the forward hemisphere. The eye can see in the visual band (400–700 nm), but has no capability in short-wave IR, mid-wave IR, and long-wave IR.	The visual sensor performance is a design criterion. Payload optics can often resolve features of a few inches at ranges of 1–20 miles. The field of regard is typically less than a full hemisphere, but greater than what a human neck permits. Optics can be made to operate in any band of the entire atmospheric transmission window.
Acoustic sensor performance	The human ear can detect sound in the 0.02–20-kHz range. The frequency range and threshold sound pressure levels vary among individuals.	Most UASs have no acoustic sensors. Microphones could be added if necessary with performance superior to the human ear.
Radio-frequency detection	Humans have no ability to detect RF signals.	UAS can transmit or receive line-of-sight and satellite RF signals with the necessary sensitivity to permit receipt of data. Typical RF communications frequencies range from 72 MHz (VHF) through 30 GHz (Ka band).
Errors	Pilot error is a major cause of manned aircraft losses. Human decision making is intuitive and imperfect.	Pilot errors are a major cause of UAS losses when pilots are in control of the unmanned aircraft. Autonomous UAS losses due to system logic errors are considered design errors.
Work duration	8–12-hr shifts, rest required between shifts.	Only limited by unmanned aircraft flight performance or reliability. 5-year duration solar-powered aircraft are feasible.
Operational service	20–30-yr career	Technology obsolete in 5–10 yrs, component service life of 100–10,000 hr
Bravery	Pilots are generally courageous and can be motivated to perform highly dangerous or suicidal (i.e., Kamikaze) missions, but pilots also have an inherent will to live.	An autopilot is indifferent to risk or self-sacrifice.
Value	Immeasurable (except by actuaries)	Hundreds to millions of U.S. dollars

Categorie

- Micro AV (MAV): $l < 15$ cm. Caratterizzati da bassa efficienza aerodinamica (bassi n. di Reynolds, $L/D = 3 \div 7$), bassa capacità di carico, avionica miniaturizzata e bassi costi di produzione.
- Small Unmanned AV (SUAV): $MTOW < 25$ kg. Solitamente modelli d'aeroplano in scala con autopilota low-cost.
- Tactical Unmanned AV (TUAV): $600 < MTOW < 25$ kg. Autonomia di 5-12 hr, altitudne max 20'000 ft.
- Medium-Altitude Long Endurance (MALE) UAV: 450 kg$<$ $MTOW$ $<$ 4.5 ton. Autonomia di 12-50 hr, altitudine 15'000-30'000 ft (motore alternativo) o 30'000-50'000 ft (turboprop).

- High-Altitude Long Endurance (HALE) UAV: $MTOW$ $>$ 2 ton. Autonomia >24 h, altitudine > 50'000 ft.
- Ultra Long Endurance (ULE) UAV. Autonomia > 5 gg, altitudine > 25'000 ft.
- Combat UAV, Conversioni da velivoli manned, droni target, rotorcraft (VTOL), UAV a energia solare, veicoli planetari (*flyers*), Lighter-then-air (LTA)

Dimensionamento preliminare

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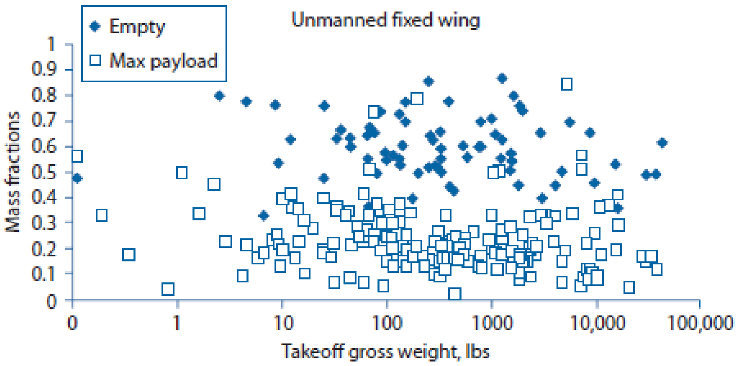
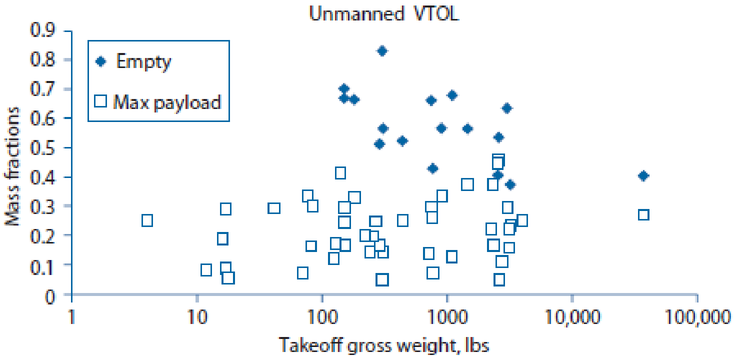
$$MF_{\text{Empty}} = \frac{W_{\text{Empty}}}{W_{\text{TO}}}$$ → *''Mass Fractions''*, frazione in massa del peso a vuoto..





$$W_{\text{TO}} = \underline{W_{\text{Struct}}} + \underline{W_{\text{Subs}}} + \underline{W_{\text{Prop}}} + W_{\text{Avion}} + W_{\text{Other}} + W_{\text{PL}} + \underline{W_{\text{Energy}}}$$

Contributi che scalano linearmente rispetto a WTO. Es:

$$W_{\text{Struct}} = \frac{W_{\text{Struct}}}{W_{\text{TO}}} \cdot W_{\text{TO}} = MF_{\text{Struct}} \cdot W_{\text{TO}}$$

$$W_{\text{TO}} = W_{\text{PL}} + W_{\text{Avion}} + W_{\text{Other}} + \left(MF_{\text{Struct}} + MF_{\text{Subs}} + MF_{\text{Prop}} + MF_{\text{Energy}}\right) \cdot W_{\text{TO}}$$ →

$$\boxed{W_{\text{TO}} = \frac{W_{\text{PL}} + W_{\text{Avion}} + W_{\text{Other}}}{1 - \left(MF_{\text{Struct}} + MF_{\text{Subs}} + MF_{\text{Prop}} + MF_{\text{Energy}}\right)}}$$

Prestazioni

$$(1 - MF_{\text{Fuel}}) = \prod_{i=1}^{NSegs} (1 - MF_{\text{Fuel,i}}) \quad \rightarrow \quad MF_{\text{Fuel}} = 1 - \prod_{i=1}^{NSegs} (1 - MF_{\text{Fuel,i}})$$

Motori alternativi e turboprop:

$$R = \frac{L/D \cdot \eta_p}{BSFC} \cdot \ell n \left(\frac{1}{1 - MF_{\text{Fuel}}} \right) \qquad MF_{\text{Fuel}} = 1 - \exp\left(\frac{-R \cdot BSFC}{L/D \cdot \eta_p} \right)$$

Motori a reazione (jet):

$$R = \frac{V \cdot L/D}{TSFC} \cdot \ell n \left(\frac{1}{1 - MF_{\text{Fuel}}} \right) \qquad MF_{\text{Fuel}} = 1 - \exp\left(\frac{-R \cdot TSFC}{V \cdot L/D} \right)$$

Propulsione elettrica:

$$E = \frac{Energy_{\text{Batt}}}{P_{\text{Batt}}}$$

$$Energy_{\text{Batt}} = Capacity \cdot Voltage \cdot \eta_{\text{Batt}} \cdot f_{\text{Usable}}$$

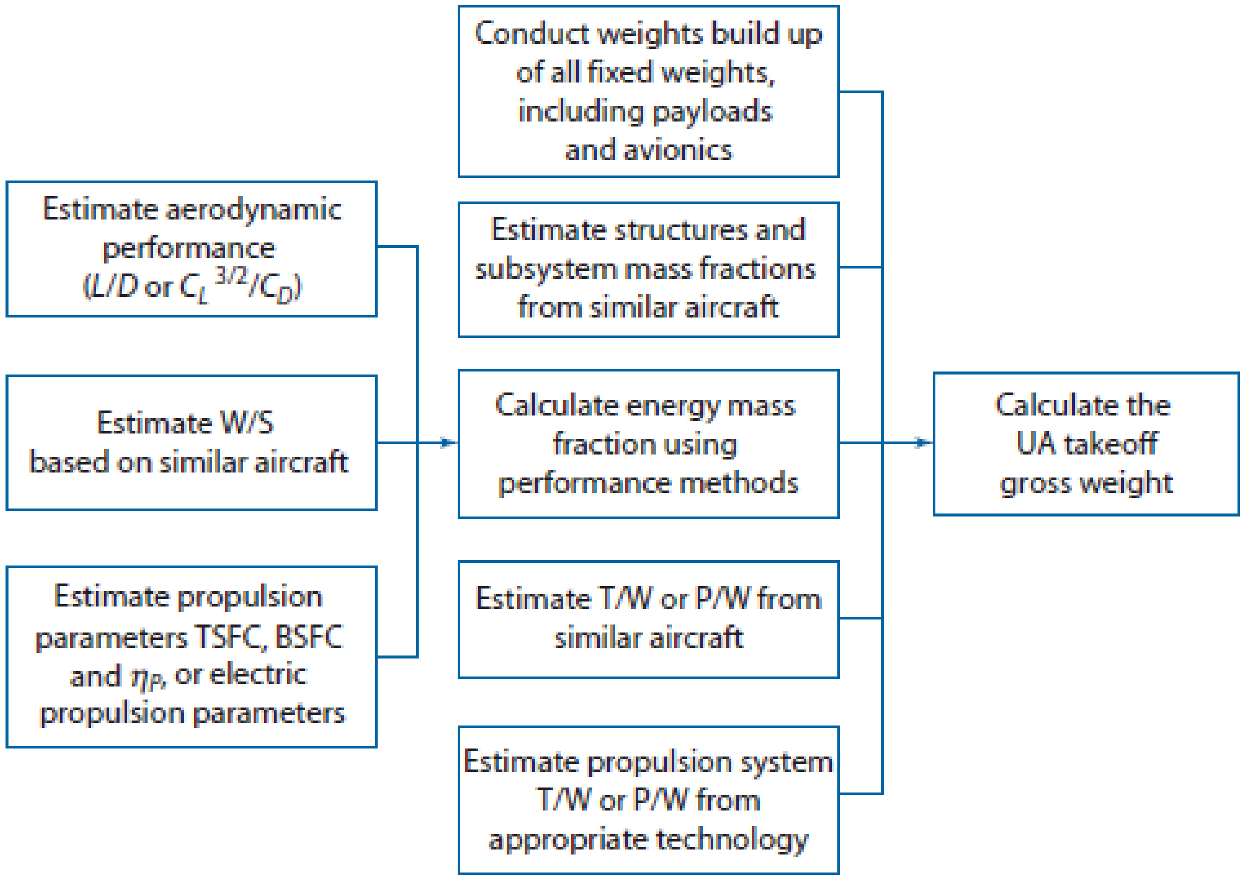
$$Energy_{\text{Batt}} = E_{\text{spec}} \cdot M_{\text{Batt}} \cdot \eta_{\text{Batt}} \cdot f_{\text{Usable}}$$

$$P_{\text{Thrust}} = T \cdot V$$

$$P_{\text{Thrust}} = D \cdot V = \frac{W_{\text{TO}}}{L/D} \cdot V$$

$$MF_{\text{Batt}} = \frac{E \cdot g}{E_{\text{Spec}} \cdot \prod \eta \cdot \eta_{\text{Batt}} \cdot f_{\text{Usable}} \cdot C_L^{3/2}/C_D} \cdot \sqrt{\frac{W_{\text{TO}}/S_w}{1/2 \cdot \rho}}$$

Dimensionamento preliminare



… un po’ più in dettaglio

1. Configurazione geometrica: ala, superfici di coda, fusoliera, integrazione propulsore, etc.
2. Aerodinamica. Es. profili alari, momento picchiante, resistenza.
3. Stima pesi.
4. Strutture: materiali, carichi, dimensionamento ala e fusoliera…
5. Sistema propulsivo.
6. Prestazioni di volo e analisi di missione.
7. Avionica, software di volo e sottosistemi.
8. Lancio e recupero, su binario, a mano, da veicolo in movimento a terra, recupero in rete, etc.
9. Sistemi di comunicazione.
10. Sistemi di misura.
11. …

Brain storming – fase 1

- Quale categoria?
- Quale payload? Quale missione?
- Quale propulsione?

Riferimenti

- J. Gundlach, Designing Unmanned Aircraft Systems: A Comprehensive Approach, AIAA Education Series, 2014.