Electric Flight – Potential and Limitations
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History and Predictions – Air Traffic

Long term fundamentals will lead to growth

Quelle: Airbus Global Market Forecast 2010 – 2029
History and Predictions – Oil Production

![Graph showing historical and predicted oil production trends for various regions.](image-url)

- Middle East
- Africa
- Latin America
- South Asia
- East Asia
- China
- Transition Economies
- OECD Pacific
- OECD Europe
- OECD North America

Ludwig-Bölkow-Systemtechnik GmbH, 2007
Electric propulsion of Aircraft?

Motivation:
- Air traffic is growing.
- Availability of fossil fuels is be limited.
- Electric propulsion systems offer high efficiencies.
- Electric propulsion systems are in situ “zero-emission”.

Specifics of air transport:
- Aircraft are already very efficient (3-4 liter/PAX/100km).
- Aircraft fly over long and very long distances (1000-10000 km).
- Mass is much more important than in ground transportation.
- Safety standards are very high.
There is nothing new under the sun...
One of the Pioneers of Electric Flight

Fred Militky
- 1940 first trials, after 1945 chief engineer at Graupner.
- Motor glider MB-E1 (HB-3, b=12 m, m = 440 kg)
  - 21. October 1973: worldwide first flight with electric motor,
  - duration 9-14 Min, altitude 360 m, Pilot Heino Brditschka,
  - performance not reached for 10 years,
  - NiCd batteries by Varta,
  - Motor by Bosch (13 PS @ 2400 1/min).
Conventional Propulsion Systems

- **Energy storage:**
  - liquid fuel,
  - alternative: Gas (e.g. H₂).

- **Conversion to propulsive power:**
  - Turbofan,
  - Turboshift / piston engine and Propeller,
  - RPM adaption as needed by a gearbox.

- Fuel is burnt, mass reduces with flight time.
Electric Propulsion

- There are many possibilities.
- Mainly two types of interest.
- **Fuel cell systems**
  - complex and still expensive,
  - usage of „conventional“ energy storage systems (Kerosene, Methanol, H2),
  - variable mass.
- **Batteries**
  - simpler systems,
  - much recent development,
  - constant mass.

also: hybrid systems
Total Efficiency
The Chain from on-board Energy to Propulsion

Turboprop
- Kerosene 100%
  - Thermodynamic Cycle $\eta=50\%$
  - Gearbox $\eta=98\%$
  - Propeller $\eta=80\%$
  - 39%

Turbofan
- Kerosene 100%
  - Thermodynamic Cycle $\eta=50\%$
  - Fan and Nozzles $\eta=65\%$
  - Propeller $\eta=80\%$
  - 33%

Battery
- Battery 100%
  - Controller $\eta=98\%$
  - Electric Motor $\eta=95\%$
  - Gearbox $\eta=98\%$
  - Propeller $\eta=80\%$
  - 73%

Fuel Cell
- Hydrogen 100%
  - Fuel Cell $\eta=60\%$
  - Controller $\eta=98\%$
  - Electric Motor $\eta=95\%$
  - Gearbox $\eta=98\%$
  - Propeller $\eta=80\%$
  - 44%
Characteristics of Energy Storage Systems
Specific Energy Content of the „pure“ Energy Carrier

![Graph showing characteristics of energy storage systems. The graph compares mass specific energy (E* [Wh/kg]) and volume specific energy (V* [Wh/liter]) for various energy carriers, including LiOH Battery, LiOH Nano-Wire Battery, NiMH Battery, NiCd-Battery, Flywheels, Pb-Battery, and others. The graph highlights the energy content of different substances such as Kerosene, LPG Propane, Ethanol, Methanol, Schlagsahne, LT, H₂ liquid, H₂ 700 bar, and H₂ 1 bar. The energy content is compared to 3.5% Vollmilch and 300 bar compressed air.]
Characteristics of Energy Storage Systems
Not Fuel Mass but System Mass is important

- Kerosene / Gas
  - Tanks, often integral part of the structure, tubing, pumps.
- Hydrogen
  - Gas: high pressure tanks (typical: 350-700 bar), tubing, … ,
  - Liquid: insulated tanks (-250 °C), insulation, tubing, … .
  - structurally integrated tanks (metal-hydrides)?
- Battery
  - Casing, heating, ventilation, wiring,
- Fuel Cell
  - compressors, water, … ,
  - Kerosene/Gas/Alcohol: reformer required.
Equivalent Energy Density of Propulsion Systems

Hydrogen Fuel Cell
- H₂
- H₂ gas
- FC \( \eta = 55\% \) (50 kg)
- Motor \( \eta = 95\% \) (25 kg)

Kerosene Reformer Fuel Cell
- Kerosene
- liquid fuel
- Reformer \( \eta = 75\% \) (33.3 kg)
- H₂ gas
- FC \( \eta = 55\% \) (50 kg)
- Motor \( \eta = 95\% \) (25 kg)

Kerosene I/C engine Generator Hybrid
- Kerosene
- liquid fuel
- I/C engine \( \eta = 35\% \) (25 kg)
- Generator \( \eta = 95\% \) (25 kg)
- Motor \( \eta = 95\% \) (25 kg)

Battery
- Battery (556 kg)
- Motor \( \eta = 95\% \) (25 kg)

Kerosene I/C engine
- Kerosene
- liquid fuel
- I/C engine \( \eta = 35\% \) (25 kg)
- shaft

E* = 551 Wh/kg
(H₂: 3306 Wh/kg)

E* = 701 Wh/kg
(Kerosene: 211800 Wh/kg)

E* = 850 Wh/kg
(Kerosene: 211800 Wh/kg)

E* = 172 Wh/kg

E* = 1575 Wh/kg
(Kerosene: 211800 Wh/kg)
Range of Aircraft with Energy Storage in Batteries

Battery

\[ E_{\text{battery}} = E^* \cdot m_{\text{battery}} \]

Aircraft

\[ E_{\text{battery}} = P_{\text{battery}} \cdot t \]
\[ = P_{\text{aircraft}} \cdot \frac{1}{\eta_{\text{total}}} \cdot t \]
\[ = D \cdot v \cdot \frac{1}{\eta_{\text{total}}} \cdot t \]
\[ = D \cdot \frac{1}{\eta_{\text{total}}} \cdot R \]
\[ = \frac{m \cdot g}{L/D} \cdot \frac{1}{\eta_{\text{total}}} \cdot R \]

\[ E^* \cdot m_{\text{battery}} = \frac{m \cdot g}{L/D} \cdot \frac{1}{\eta_{\text{total}}} \cdot R \]

\[ R = E^* \cdot \eta_{\text{total}} \cdot \frac{1}{g} \cdot \frac{L}{D} \cdot \frac{m_{\text{battery}}}{m} \]

\( E^* = \) Energy per mass [J/kg, Ws/kg]
\( P = \) power [W]
\( L/D = \) lift over drag
\( t = \) time [s]
\( v = \) flight speed [m/s]
\( m = \) aircraft mass [kg]
\( R = \) range [m]
\( g = 9.81 \) [m/s\(^2\)]
\( \eta = \) total efficiency from battery

(neglecting fuel reserves as well as takeoff and landing)
Range of Aircraft

- Energy from decomposing / burning fuel (hot or cold):
  - Fuel consumption reduces mass during the flight time.
  - Classical range equation ("Breguet-equation") applies.

\[
R = E^* \cdot \eta_{\text{total}} \cdot \frac{1}{g} \cdot \frac{L}{D} \cdot \ln \left( \frac{1}{1 - \frac{m_{\text{fuel}}}{m}} \right)
\]

- Energy drawn from batteries or solar energy:
  - Mass stays constant.

\[
R = E^* \cdot \eta_{\text{total}} \cdot \frac{1}{g} \cdot \frac{L}{D} \cdot \frac{m_{\text{battery}}}{m}
\]
Impact of variable Mass on Range

- Aircraft with a small mass fraction $m_{\text{fuel}}/m$ of energy storage experience a small effect.
- Short range aircraft lose about 5-10% in range.
- Long range aircraft lose about 20-25% of range.
- This effect must be compensated by additional energy or efficiency.

$$R = E^* \cdot \eta_{\text{total}} \cdot \frac{1}{g} \cdot \frac{L}{D} \cdot \ln \left( \frac{1}{1 - \frac{m_{\text{fuel}}}{m}} \right)$$

$$R = E^* \cdot \eta_{\text{total}} \cdot \frac{1}{g} \cdot \frac{L}{D} \cdot \frac{m_{\text{battery}}}{m}$$

![Graph showing the impact of fuel mass fraction on range]

$\Rightarrow$ fuel mass fraction $\Rightarrow$
Range of Aircraft with Energy Storage in Batteries

⇒ Range with payload

\[
R = E^* \cdot \eta_{\text{total}} \cdot \frac{1}{g} \cdot \frac{L}{D} \cdot \left( 1 - \frac{m_{\text{empty}}}{m} - \frac{m_{\text{payload}}}{m} \right)
\]

⇒ How large is the maximum range with a given technology?
⇒ payload → zero

\[
R_{\text{ult}} = E^* \cdot \eta_{\text{total}} \cdot \frac{1}{g} \cdot \frac{L}{D} \cdot \left( 1 - \frac{m_{\text{empty}}}{m} \right)
\]

⇒ This limit cannot be exceeded.
⇒ Limit case, allows for a rapid assessment of “weird” concepts, realistic ranges are always lower!
Sizing Equation
Determine required Aircraft Mass for Range

- rearranging the range equation yields the aircraft mass for a given range

\[
m = \frac{\text{PAX} \cdot m_{\text{pax}}}{1 - \frac{m_{\text{empty}}}{m} - \frac{g}{E^* \cdot \eta_{\text{total}} \cdot L/D} \cdot R}
\]

- only a small number of parameters needed:
  - desired range \( R \),
  - number of passengers \( \text{PAX} \) and mass per \( \text{PAX} \) \( m_{\text{pax}} \),
  - empty mass fraction \( m_{\text{empty}}/m \),
  - specific energy \( E^* \) of the battery system,
  - total efficiency of the system from battery to thrust,
  - lift over drag ratio \( L/D \).
  - no direct influence of cruise altitude!
  - for \( R=0 \) we obtain the absolute minimum mass of the aircraft.
Sizing Limits

- Aircraft mass for given range
  \[ m = \frac{PAX \cdot m_{pax}}{1 - \frac{m_{empty}}{m} - \frac{g}{E^* \cdot \eta_{total} \cdot L / D}} \]

- Constraints for solution (m > 0)
  \[ \frac{L}{D} > \frac{R \cdot g}{(1 - m_{empty}/m) \cdot E^* \cdot \eta_{total}} \]
Sizing Limits

- Aircraft mass for given range

\[ m = \frac{PAX \cdot m_{pax}}{1 - \frac{m_{empty}}{m} - \frac{g}{E^* \cdot \eta_{total} \cdot L / D}} \]

- Constraints for solution (\( m > 0 \))

\[ \frac{L}{D} > \frac{R \cdot g}{(1 - \frac{m_{empty}}{m}) \cdot E^* \cdot \eta_{total}} \]

\[ E^* > \frac{R \cdot g}{(1 - \frac{m_{empty}}{m}) \cdot \eta_{total} \cdot L / D} \]
Sizing Limits

- Aircraft mass for given range

\[
m = \frac{\text{PAX} \cdot m_{\text{pax}}}{1 - \frac{m_{\text{empty}}}{m} - \frac{g}{E^* \cdot \eta_{\text{total}} \cdot L / D}} \cdot R
\]

- Constraints for solution \((m > 0)\)

\[
\frac{L}{D} > \frac{R \cdot g}{(1 - m_{\text{empty}}/m) \cdot E^* \cdot \eta_{\text{total}}}
\]

\[
E^* > \frac{R \cdot g}{(1 - m_{\text{empty}}/m) \cdot \eta_{\text{total}} \cdot L / D}
\]

\[
\frac{m_{\text{empty}}}{m} < 1 - \frac{R \cdot g}{E^* \cdot \eta_{\text{total}} \cdot L / D}
\]
Refined Model

- Aircraft geometry and structures
  - wing span, wing area, empty mass fraction.
- Aerodynamics
  - „square“ polar, zero lift drag, k-factor.
- System
  - Battery: E*, U(t); Motor: P(U), efficiencies.
- Propeller
  - diameter, speed, number → efficiency = f(T, v, H).
- Energy optimized mission
  - climb with optimum speed (incl. propeller),
  - cruise with optimum speed (incl. propeller),
  - descent with max. L/D (only secondary energy consumption),
  - no reserves!
| Type       | Symbol | Units | Performance Aircraft | Cruiser Aircraft | Cruiser Aircraft | Cruiser Aircraft | Cruiser Aircraft | Regional Aircraft | Regional Aircraft |
|------------|--------|-------|----------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Example    |        |       | Lange Antares 20E    | Pipistrel Taurus | IFB E-Genius     | IFB E-Genius     | Pipistrel Panthera | Fairchild Do 328 | Focke-Wulf Condor |
| Geometry   |        |       |                      |                  |                  |                  |                  |                  |                  |                  |
|           | b      | m     | 20                   | 15.0             | 16.7             | 16.7             | 10.9             | 21.0             | 32.8             |
|           | S      | m²    | 12.6                 | 12.3             | 14.3             | 14.3             | 10.9             | 40               | 118              |
|           | AR     | -     | 31.8                 | 18.2             | 19.9             | 19.9             | 10.8             | 11               | 9.1              |
| Payload   | PAX    | -     | 1                    | 2                | 1                | 2                | 2                | 32               | 30               |
|            | L/D    | -     | 42                   | 32               | 38               | 38               | 29               | 16               | 16               |
| Aero      | m/S    | kg/m² | 42.1                 | 44.2             | 59.2             | 59.7             | 110.1            | 397              | 131.8            |
|           | m²/kg² |       | 1.3                  | 2.4              | 3.0              | 3.0              | 10.2             | 36.1             | 14.5             |
|           | C_D,0  |       | 0.0118 \(^{(2)}\)   | 0.0142 \(^{(2)}\)| 0.0103           | 0.0103           | 0.0100           | 0.0306           | 0.0250           |
| Masses    | m      | kg    | 530                  | 545              | 850              | 850              | 1200             | 15880            | 15400            |
|           | m_{empty} | kg  | 360                  | 264              | 450              | 450              | 500              | 8500             | 9700             |
|           | m_{battery} | kg  | 80                   | 101              | 310              | 220              | 520              | 4500             | 3000             |
|           | m_{empty}/m | -   | 0.68                 | 0.48             | 0.53             | 0.53             | 0.42             | 0.54             | 0.63             |
|           | m_{battery}/m | - | 0.15                | 0.19             | 0.37             | 0.26             | 0.43             | 0.28             | 0.19             |
|           | m_{payload}/m | - | 0.17                | 0.33             | 0.10             | 0.21             | 0.15             | 0.18             | 0.18             |
| Battery power | P_{climb} | kW | 47                   | 46               | 67               | 67               | 139              | 3799             | 2605             |
|            | P_{cruise} | kW | 5                    | 8                | 11               | 11               | 33               | 1102             | 690              |
| Range     | R_{powered} | km | 126                  | 141              | 495              | 316              | 462              | 157              | 88               |
|           | R | km    | 282                  | 259              | 613              | 435              | 548              | 206              | 131              |
|           | R_{ultimate} | km | 622                  | 774              | 835              | 835              | 776              | 351              | 280              |
|           | L - l_c - l_p | - | 0.15                 | 0.19             | 0.37             | 0.26             | 0.43             | 0.28             | 0.20             |
|           | E^* η/L/D/g | km | 1960                 | 1436             | 1800             | 1800             | 1330             | 765              | 758              |
| Time      | t_{powered} | h  | 1.29                 | 1.3              | 3.9              | 2.5              | 2.3              | 0.5              | 0.5              |
|           | t | h    | 2.4                  | 2.2              | 4.8              | 3.4              | 2.6              | 0.7              | 0.6              |
| Verbrauch | E_{spec} | Wh/PAX/km | 49                  | 34               | 89               | 45               | 84               | 120              | 134              |
| Kerosin   | E_{equiv} | l/PAX/100km | 1.05                | 0.73             | 2.04             | 1.02             | 1.92             | 2.79             | 3.02             |
| Altitude  | H | m    | 3000                 | 3000             | 3000             | 3000             | 3000             | 3000             | 3000             |
\[ R = \left(1 - \frac{m_{\text{empty}}}{m} - \frac{m_{\text{payload}}}{m}\right) \cdot \frac{E^* \cdot \eta_{\text{total}} \cdot L}{D \cdot g} \]

\[ H_{\text{cruise}} = 3000 \text{ m}, \quad E^* = 180 \text{ Wh/kg}, \quad \eta_{\text{total}} = 70\% \]

- **Lange Antares 20E**
  - 1 PAX
  - \( R_p = 126 \text{ km} \)
  - \( R = 282 \text{ km} \)
  - \( E_{\text{spec}} = 49 \)

- **Pipistrel Taurus**
  - 2 PAX
  - \( R_p = 141 \text{ km} \)
  - \( R = 259 \text{ km} \)
  - \( E_{\text{spec}} = 34 \)

- **IFB E-Genius**
  - 1 PAX
  - \( R_p = 495 \text{ km} \)
  - \( R = 613 \text{ km} \)
  - \( E_{\text{spec}} = 89 \)

- **IFB E-Genius**
  - 2 PAX
  - \( R_p = 316 \text{ km} \)
  - \( R = 435 \text{ km} \)
  - \( E_{\text{spec}} = 45 \)

- **Pipistrel Panthera**
  - 2 PAX
  - \( R_p = 462 \text{ km} \)
  - \( R = 548 \text{ km} \)
  - \( E_{\text{spec}} = 84 \)

- **Fairchild Do 328**
  - 32 PAX
  - \( R_p = 157 \text{ km} \)
  - \( R = 206 \text{ km} \)
  - \( E_{\text{spec}} = 120 \)

- **Focke-Wulf Condor**
  - 30 PAX
  - \( R_p = 88 \text{ km} \)
  - \( R = 131 \text{ km} \)
  - \( E_{\text{spec}} = 134 \)

\( E_{\text{spec}} \) in Wh/PAX/km
Example: Regional Aircraft

The range of the aircraft with 32 passengers is about 1200 km.

With full tanks and 28 passengers it grows to 2200 km.

The lift over drag ratio is about 16.

Modification:
Replacing fuel system and engines by an electric system of identical mass.

With current technology the aircraft would reach a range of 202 km, however without any reserves (with reserves: R=50 km).

Baseline

- $m = 16200 \text{ kg}$
- $b = 21 \text{ m}$
- $C_{p.o} = 0.0306$
- $\hat{E} = 180 \text{ Wh/kg}$
- $R = 202 \text{ km}$
- $t = 0.67 \text{ h}$
- $E_{\text{spec}} = 123 \text{ Wh/PAX/km}$
$C_{D,0}$

zero lift drag reduced by 20%

baseline 328

- $m = 16200 \text{ kg}$
- $b = 21 \text{ m}$
- $C_{D,0} = 0.0306$
- $E^* = 180 \text{ Wh/kg}$
- $R = 202 \text{ km}$
- $t = 0.67 \text{ h}$
- $E_{\text{spec}} = 123 \text{ Wh/PAX/km}$

328-L

- $m = 16200 \text{ kg}$
- $b = 21 \text{ m}$
- $C_{D,0} = 0.0245$
- $E^* = 180 \text{ Wh/kg}$
- $R = 221 \text{ km}$
- $t = 0.67 \text{ h}$
- $E_{\text{spec}} = 112 \text{ Wh/PAX/km}$
$C_{D,0}$

zero lift drag reduced by 20%

328-L

- $m = 16200$ kg
- $b = 21$ m
- $C_{D,0} = 0.0245$
- $E^* = 180$ Wh/kg
- $R = 221$ km
- $t = 0.67$ h
- $E_{\text{spec}} = 112$ Wh/PAX/km

328-LB

- $m = 16200$ kg
- $b = 31.5$ m
- $C_{D,0} = 0.0245$
- $E^* = 180$ Wh/kg
- $R = 302$ km
- $t = 1.10$ h
- $E_{\text{spec}} = 82$ Wh/PAX/km

span increased by 50%
\[ m = 16200 \text{ kg} \]
\[ b = 31.5 \text{ m} \]
\[ C_{D,0} = 0.0245 \]
\[ E^* = 180 \text{ Wh/kg} \]
\[ R = 302 \text{ km} \]
\[ t = 1.10 \text{ h} \]
\[ E_{\text{spec}} = 82 \text{ Wh/PAX/km} \]

**328-LB**

\[ m = 14500 \text{ kg} \]
\[ b = 31.5 \text{ m} \]
\[ C_{D,0} = 0.0245 \]
\[ E^* = 180 \text{ Wh/kg} \]
\[ R = 339 \text{ km} \]
\[ t = 1.32 \text{ h} \]
\[ E_{\text{spec}} = 73 \text{ Wh/PAX/km} \]

**328-LBM**

span increased by 50%
empty mass reduced by 20%
\( m_e \)

empty mass reduced by 20%

\( E^* \)

\( E^* \) doubled to 360 Wh/kg

---

**328-LBM**

\( m = 14500 \text{ kg} \)
\( b = 31.5 \text{ m} \)
\( C_{D,0} = 0.0245 \)
\( E^* = 180 \text{ Wh/kg} \)
\( R = 339 \text{ km} \)
\( t = 1.32 \text{ h} \)
\( E_{\text{spec}} = 73 \text{ Wh/PAX/km} \)

**328-LBME**

\( m = 14500 \text{ kg} \)
\( b = 31.5 \text{ m} \)
\( C_{D,0} = 0.0245 \)
\( E^* = 360 \text{ Wh/kg} \)
\( R = 711 \text{ km} \)
\( t = 2.89 \text{ h} \)
\( E_{\text{spec}} = 70 \text{ Wh/PAX/km} \)
E* doubled to 360 Wh/kg

328-LBME

m = 14500 kg
b = 31.5 m
C_{D,0} = 0.0245
E^* = 360 Wh/kg
R = 711 km
\( t = 2.89 \) h
E_{spec} = 70 Wh/PAX/km

E* increased to 720 Wh/kg

328-LBME^2

m = 14500 kg
b = 31.5 m
C_{D,0} = 0.0245
E^* = 720 Wh/kg
R = 1455 km
\( t = 6.02 \) h
E_{spec} = 68 Wh/PAX/km
**Big Steps in Technology Development are Required.**

> Energy optimized flight:

> - The cruise speed drops due to higher wing span below 300 km/h
  (The turboprop variant flies at 480 km/h.)

> - L/D = 16 → 27.5

> - The high aspect ratio requires high lift coefficients (climb: 0.9, cruise: 1.2).

> - Consumption with a turboprop would be about 1.5 Liter/PAX/100km

\[
\begin{align*}
m &= 14500 \text{ kg} \\
b &= 31.5 \text{ m} \\
C_{D,0} &= 0.0245 \\
E^* &= 720 \text{ Wh/kg} \\
R &= 1455 \text{ km} \\
t &= 6.02 \text{ h} \\
E_{\text{spec}} &= 68 \text{ Wh/PAX/km}
\end{align*}
\]
Note on Range Flexibility

Trading fuel / batteries for range is more useful for (lightweight) kerosene than for (heavy) batteries.
Battery Powered Aircraft?

Conclusions:
- Electric propulsion systems with batteries are possible for small aircraft,
- The range is strongly limited, but useable for General Aviation and UAVs,
- For larger aircraft the battery technology must be drastically improved to at least 1000 Wh/kg (factor 5),
  This seems to be unlikely within the next 10 years, but may be within 20-40 years.
- Costs are less relevant as they will shrink due to automotive and consumer industry.

Many Open Questions:
- What is the total balance including production and recycling?
  - Are the raw materials for automotive and aviation available in the long term?
  - What happens in hydrogen technology (storage problem)?
  - What happens in fuel cell technology (cost, efficiency)?
  - Should we better use bio fuels, alcohol, synthetic fuels or hydrogen in conventional propulsion systems?
- What about safety of electric propulsion systems?
  - We are not (yet) accustomed to all-electric aircraft,
  - Fire in case of damage or crash, effects when ditching in water,
  - Electric interference (high voltages and currents vs. mobile phones).
There is nothing new under the sun...
One of the Pioneers of Electric Flight

Fred Militky
- 1940 first trials, after 1945 chief engineer at Graupner.
- Motor glider MB-E1 (HB-3, b=12 m, m = 440 kg)
  - 21. October 1973: worldwide first flight with electric motor,
  - duration 9-14 Min, altitude 360 m, Pilot Heino Brditschka,
  - performance not reached for 10 years,
- NiCd batteries by Varta,
- Motor by Bosch (13 PS @ 2400 1/min).

Today, 40 years later, using commercially available battery systems, the flight time could be extended to 2.5 hours.
Return to the Future with Whole Milk?

Thank You for Listening!