Modern electric propulsion systems for small MAV's

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ENSICA
Toulouse

Journées
Micro-drones 2002

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DYNAMIC ENGINEERING

Contents

- Developments in batteries
- Developments in motors
- Developments in speed controllers
- System integration

Short Battery History

- First flights with Lead Acid and Silver Zinc and salt water batteries. Fred Militky, Bob Boucher.
- Around 1970 fast charge-discharge NiCad's became available from Saft, later GE and Sanyo
  Steady improvement of power- and energy-density
- Around 1990 the first usable NiMH cells become available
  Good energy density
  From about 2000 significantly increased power density
- Around 2000 the first usable Lithium Ion cells become available with an excellent energy density but a maximum discharge rate of only 2 C

New Lithium Batteries

- In 2002 Kokam from Korea introduces their new range of high rate Lithium Ion and Lithium Polymer Batteries
- The high rate capability is well suited to model flight and superior to other Lithium technologies

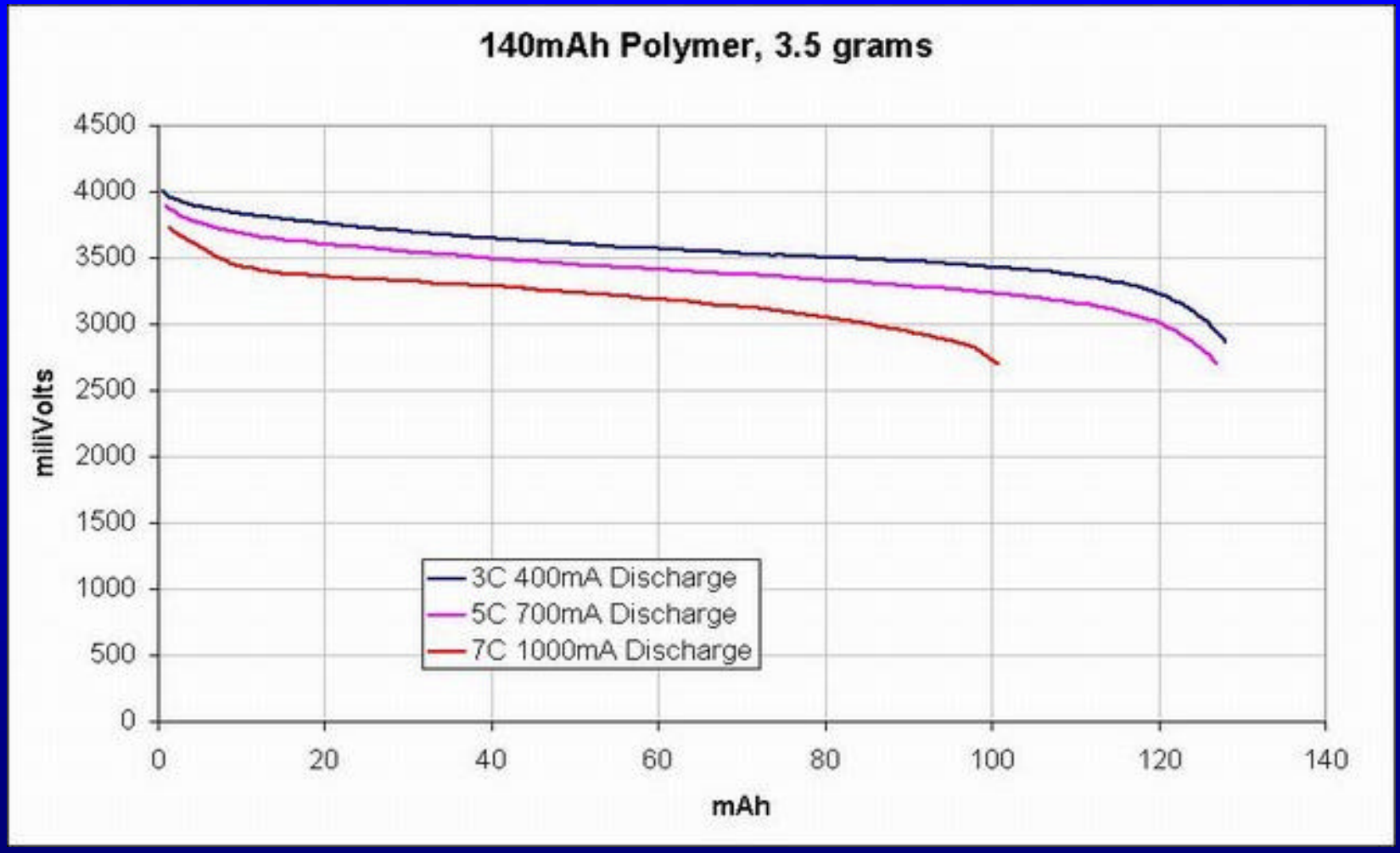
Energy density	Wh/kg
High rate NiCd	50
High Capacity NiCd	60
High Capacity NiMH	70
Superior Lithium Polymer	180

Kokam 145 mAh Lithium

- The Kokam 145 mAh battery designed for Bluetooth is exceptional and easily delivers 7 C continuous.
- Power density almost 3 times the best small NiCd
- Power density almost 6 times the best small NiMH

Power density	W/kg
50 mAh Sanyo NiCd	300
160 mAh GP NiMH	150
145 mAh Kokam LiPoly	890

Kokam 145 mAh Lithium



Kokam 145 mAh Lithium

- The 145 mAh battery is exceptional and no other technology can compete with them.
- Energy density more than 9 times the best small NiCd.
- Energy density 3 times the best small NiMH.

Energy density	Wh/kg
50 mAh Sanyo NiCd	16
160 mAh GP NiMH	51
145 mAh Kokam LiPoly	150

Kokam 145 mAh Lithium

The Kokam SLB 145 mAh with 3 NiCd cells of 50 mAh

Kokam, Lithium range

Range of Kokam Lithium cells to be available soon

49 mAh	1020 mAh
145 mAh	1575 mAh
560 mAh	2070 mAh
880 mAh	3270 mAh

Lithium, Safety

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- Lithium Polymer batteries are inherently less sensitive (dangerous) than Lithium Ion
- Flat pack cells are less dangerous than cylindrical cells, they swell rather than explode at severe misuse
- Suitable safety circuits are required to avoid danger to the user, equipment or cell itself

Lithium, Safety

Safety circuits

- Over voltage protection during charge, individual cell
- Under voltage protection at discharge, individual cell
- Over current protection, for whole battery pack

- Cell is disconnected from load in protection mode

Lithium, Safety

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  Radio system shall remain powered-up all the time
- We are now developing new dedicated R/C safety systems in co-operation with FMA in the USA, Kokam and a Korean company specialised in Lithium safety circuits

Motor Development

Short Motor History

- The first usable electric electric flight motors were the Mabuchi's in the 300 and 500 series
- The first good motors came with Keller (D) and Astro (USA). They used Cobalt-Samarium magnets
- Many good motors followed, still with carbon brushes
- The magnets were replaced by Neodym Iron Boron magnets that are still more powerful
- In the late 80's the first brushless motors were build by individual modellers

Brushless Motors

- In the late 90's with the advances in μ–controller and FET technology the brushless motor becomes widely available
- The brushless motor yields a higher efficiency and higher reliability usually at a lower weight
- Two pole motors are used for simplicity and high rpm
- Four and 6 pole motors are used for higher torque installations
- Good, real small brushless motors are still not available

LRK Outrunner Motor

- Around 2000 another winding and magnet technique is adapted to model motors. Known since as LRK motor
- It uses a 12 pole stator with 6 active and 6 passive poles, and a rotor with 14 magnet segments
- The rotor turns at 1/7th the speed of the stator field
  The LRK has a very high torque at rather low rpm
  A big propeller can be used without a gearbox
  The motor cannot spin fast, due to the high frequency the commutation becomes inefficient
- LRK seems optimal for medium and large motor sizes
- The LRK is usually made as an outrunner

Motor Development

- All the new motor developments were initiated by individual skilled and well educated modellers
- The big model firms usually came 5 years later

Micro Brushless

- Many individual modellers try converting CD-ROM motors to mini-micro-model motors
- Most of these home build motors run, some with a better efficiency than the cheap brushed motors, but many don’t even reach that
- CD-ROM motors are very much cost-optimised and tuned for their special task only
- CD-ROM motors are not designed for high torque
- CD-ROM motors usually have 9 stator poles and 12 magnets. Results in 1:2 reduction (as a 4 pole motor)

Micro Brushless

- The magnet system of CD-ROM motors is too weak
- Their winding technique is cost optimised and only suited for many turns per pole
- The bearing system is optimised for low noise and cost price and often has too much friction

- Some parts of CD-ROM motors are well suitable for model motors, reducing the cost price

Micro Brushless

- A good micro motor has been developed in two sizes
- A stator of a small high volume CD-ROM motor is used
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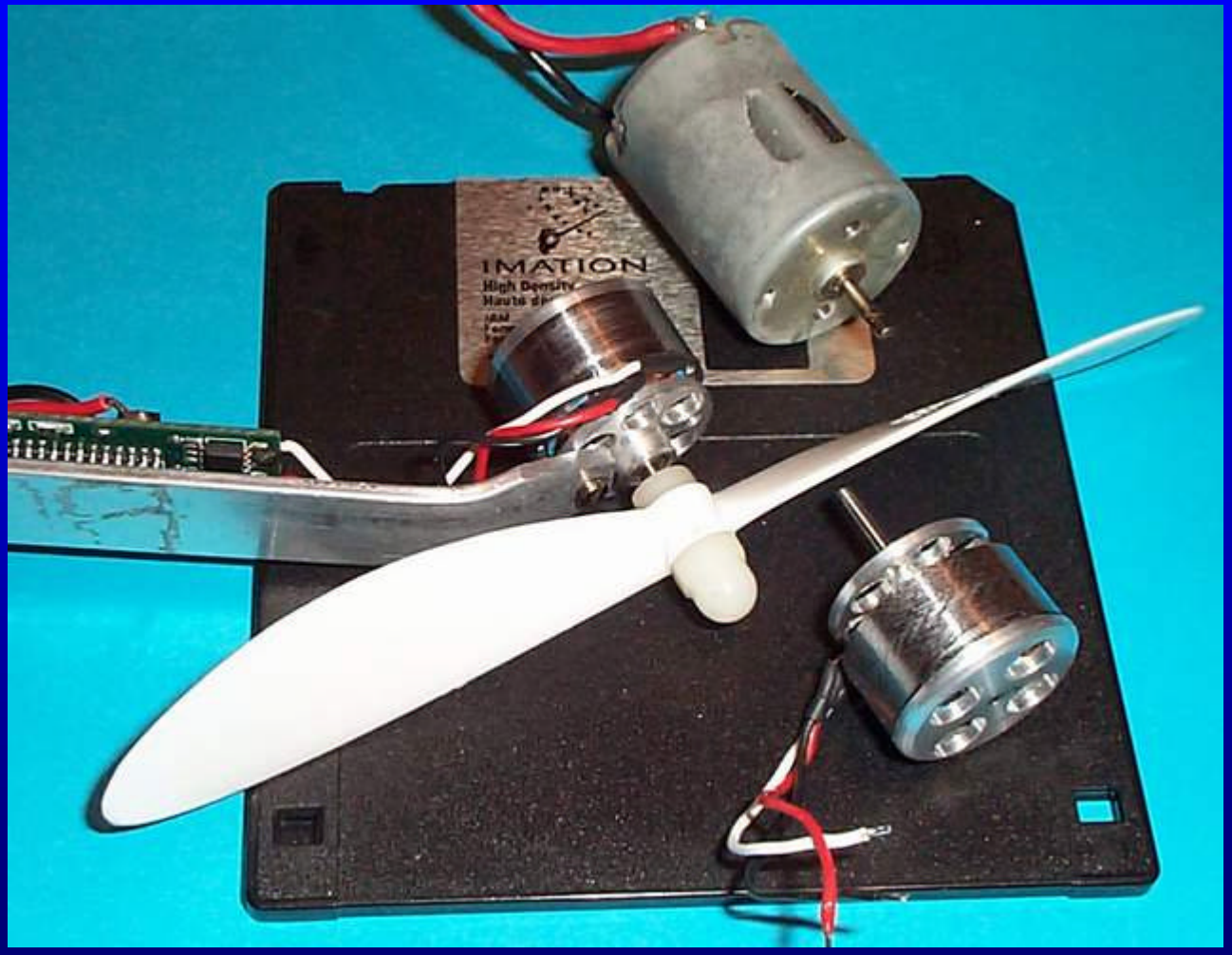
Motor	Weight incl. controller	Efficiency
Speed 280	45	100
Astro 010	50	130
RR21BL long	20	150
RR21BL short	13	130

Micro Brushless



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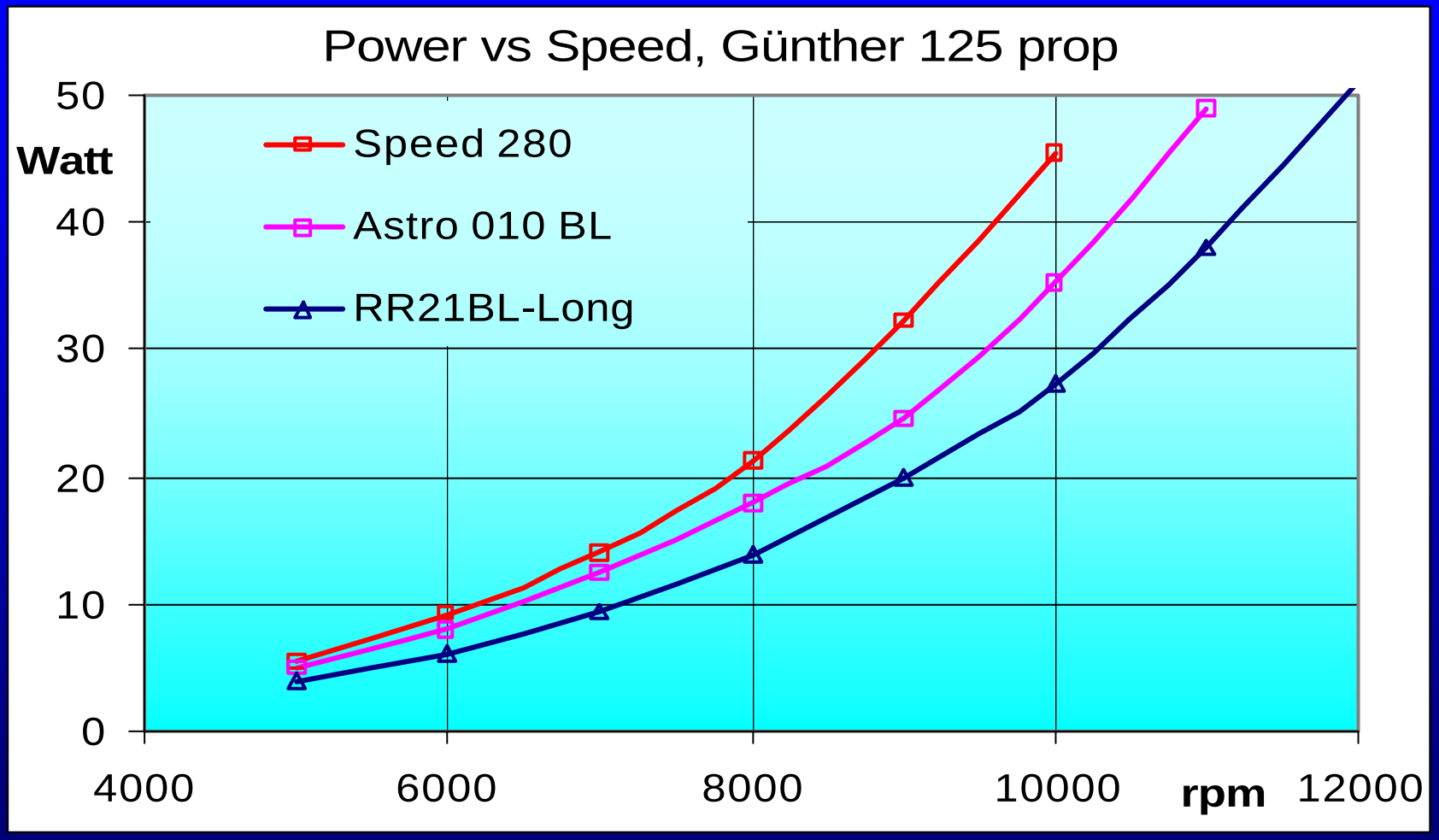

Micro Brushless Controller

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- 4 amp continuous current
- 1.5 Amp BEC
- Voltage cut-of is soft-select to 2 or 3 Lithium cells

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- At this moment the controller is being tuned to allow good start-up, efficiency and power

Micro Brushless Controller

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System Integration

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S.I. Constant Autonomy

- To get the same output power and endurance as a speed 280 with 7 cells 600 mAh NiMH we need less weight with the new technology propulsion systems Two 550 mah LiPo cells will give the same autonomy

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Controller	2	4
Total	120	45

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- We can take 75 grams of extra payload with the new propulsion system

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- We have four times the autonomy with the new propulsion systems

Thank you
for your attention

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