

# 太陽能無人機新科技

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# OUTLINE

- ▶ Introduction
  - Why Solar?
- ▶ Power conditions of solar drone
  - Power consumption of drone
  - Power generation of solar cells
- ▶ Solar quadcopter
  - How to achieve longest flight: 3 hours 28 minutes?
- ▶ Solar fixed-wing
  - How to achieve longest flight: 3 hours 23 minutes?
- ▶ Conclusion

## ▶ Liquid Fuel

- High energy density for long flight time
- Explosive, very dangerous

## ▶ Battery

- Safe
- Limited capacity, short flight time
- Typically less than 30 minutes



## ► Fixed Wing

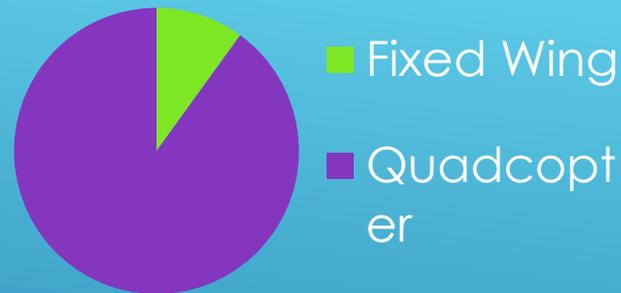
- Needs runway
- Consumes less power

## ► Copter

- Takes off and lands vertically, easy to use
- Consumes more power
- Much more **user-friendly**

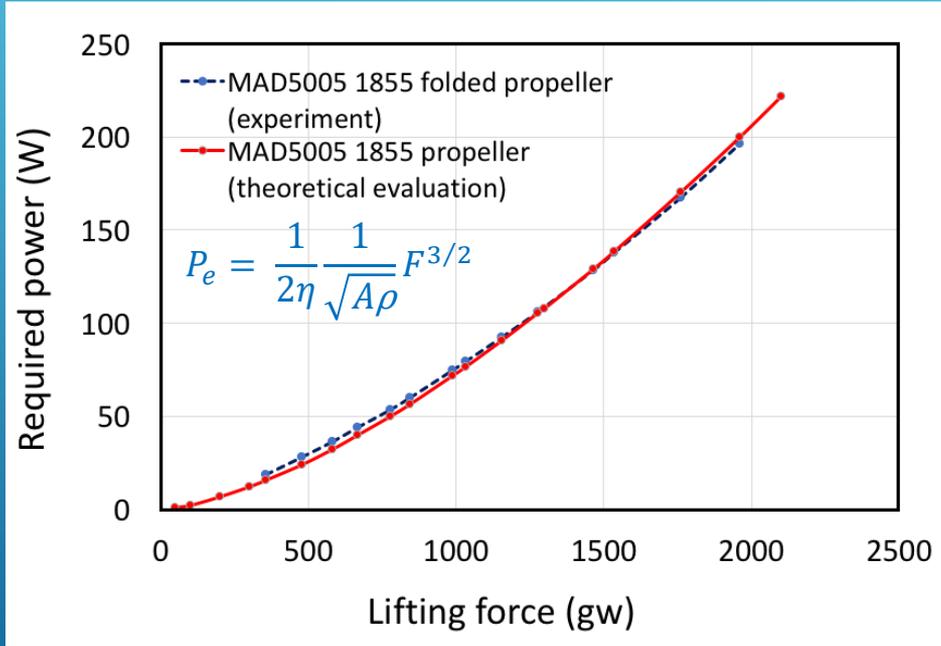


## Market share (Equity Research)



# INTRODUCTION

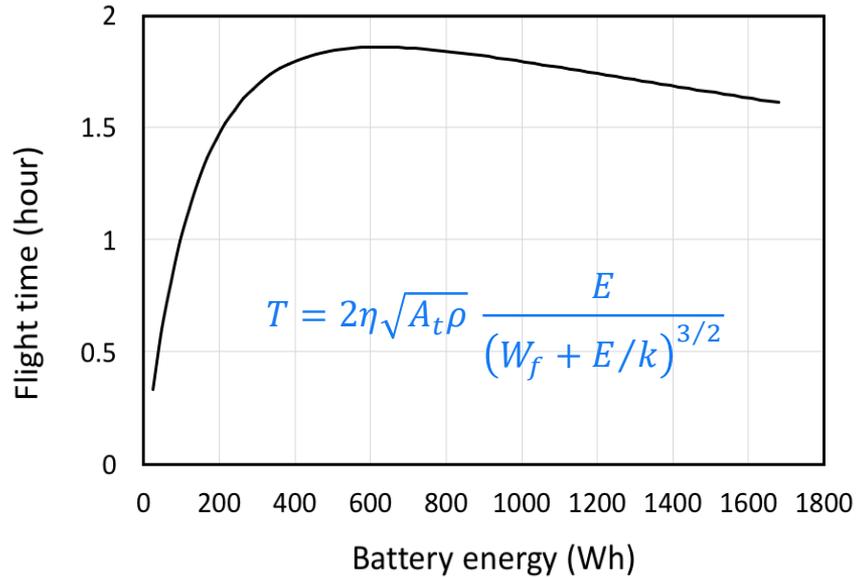
# POWER CONSUMPTION OF DRONE



## Two opposite effects could happen:

- high-spinning speed making the air stream more directional, so increasing efficiency
- increased temperature of motors decreasing the overall efficiency

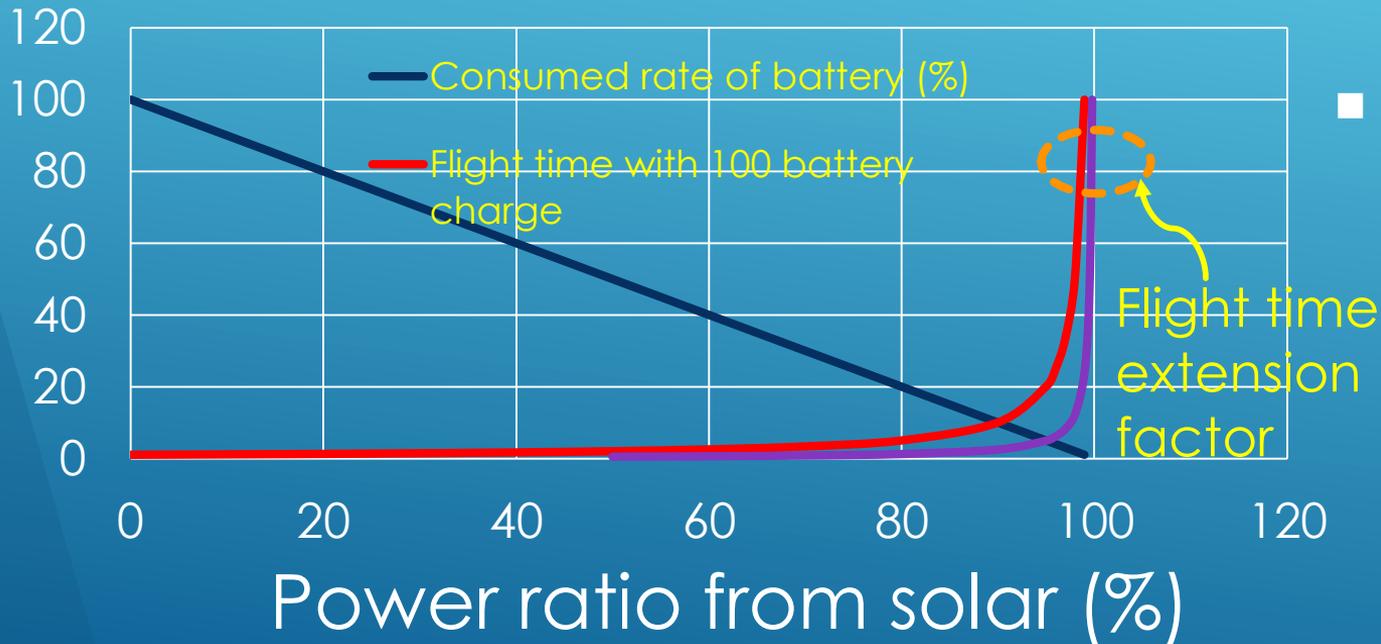
# FLIGHT TIME VARIATION WITH BATTERY CHARGE



- For a battery, the energy  $E$  is proportional to its weight  $W_b$ ,  $E = kW_b$ , with  $k$  approximately equal to 0.2 Wh/g
- the flight time does not always increase with the battery energy because the consumed power super-linearly increases with the total weight of the copter.

# EVALUATION OF FLIGHT TIME WITH SOLAR

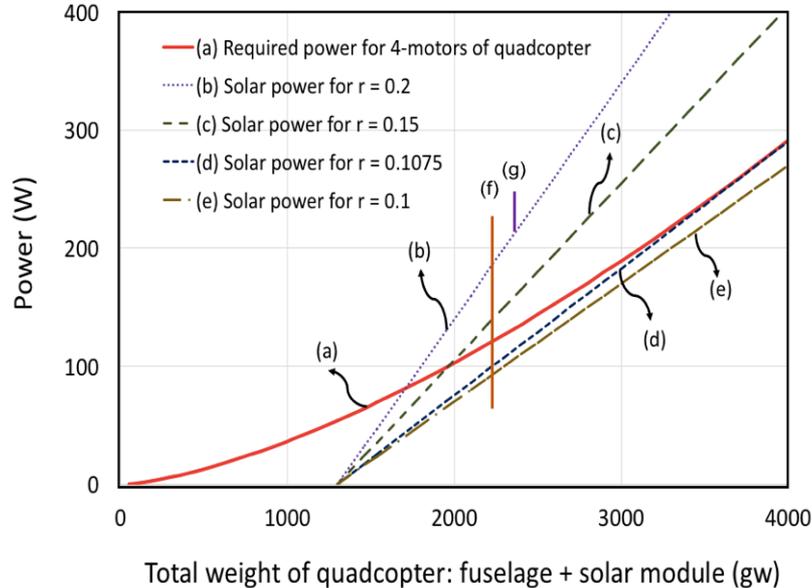
## Flight time with sunlight



- Flight time increases as the ratio of power from sunlight increases
- The extended factor becomes significant when the ratio is above 90%.

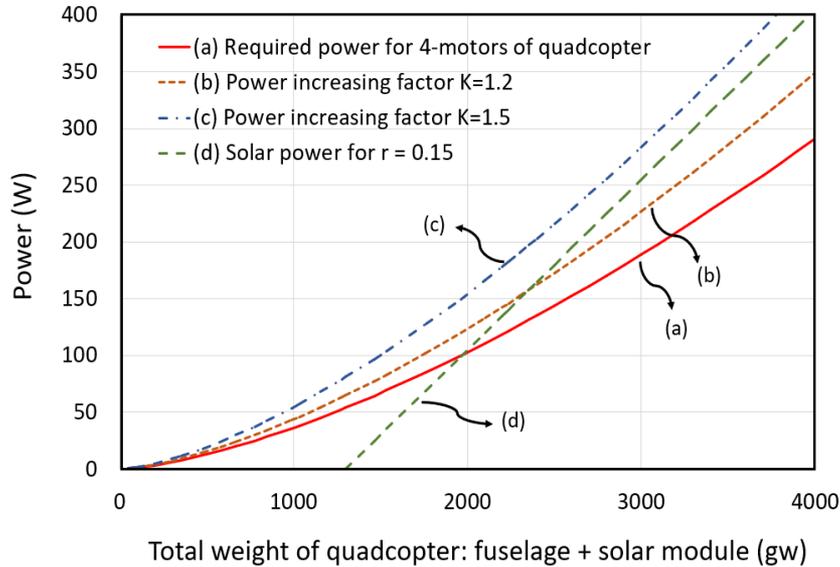


# POWER GENERATION FROM SOLAR MODULES



- (a) shows necessary thrust, curves
- (b-e) show hypothetical power available from solar modules with different PWR
- line (f): experimental power variation for a 2230-g solar-quadcopter operated under solar power only, with huge fluctuation,
- line (g): the power range of a 2350-g solar quadcopter operating under varying sun orientation on September 19, 2018 at a latitude of  $24.5^\circ$ .

# PRACTICAL POWER CONSUMPTION OF DRONE



- (a-c) shows necessary thrust of quadcopter for different power increasing factor, depending on the copter's configuration, flight attitude, wind, ...etc.
- (d) available power from solar module.
- Only (a) and (b) intersect (d), indicating sufficient power.

# SOLAR QUADCOPTER

## ▶ Electrical Spec

▶ 5s: 18.5~21.0V

▶ 6s: 22.2~25.2V

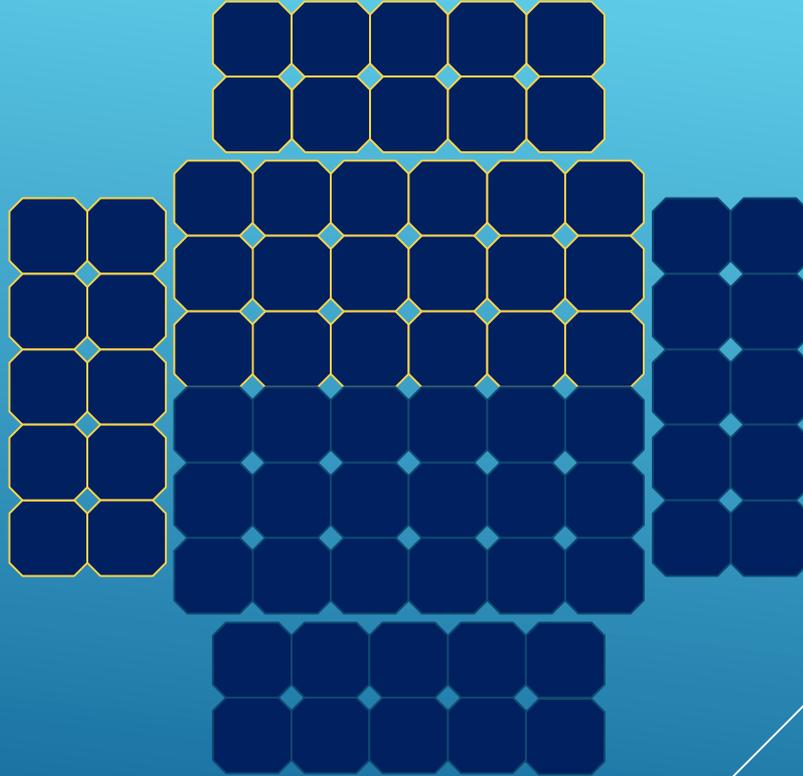
## ▶ Solar cells have to be wired to match the voltage

▶ 5s : 38 5" Si solar cells in series, 2 in parallel

▶ 6s : 43 5" Si solar cells in series, 2 in parallel

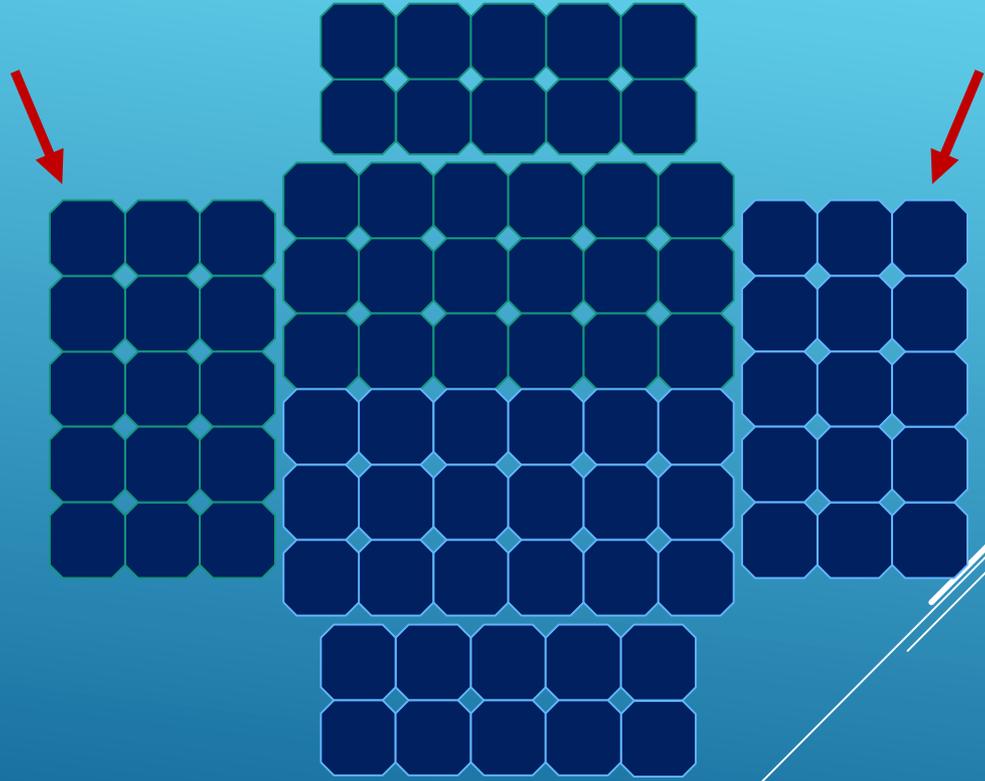
# SOLAR MODULE I

5s: 38 5" Si solar  
cells in series,  
2 in parallel



# SOLAR MODULE II

6s: 43 Si 5" solar  
cells in series,  
2 in parallel



# QUADCOPTER WITH SOLAR MODULE



	#1	#2	#3	#4
Solar Module Power	240 W	160 W	210 W	81 W
Total Voltage	3s (12V)	6s (24V)	6s (24V)	5s (20V)
Frame Weight	1300 gw	740 gw	1100 gw	520 gw
Solar Module Weight	1100 gw	510 gw	700 gw	310 gw
Frame Size	1300 mm	1200 mm	1200 mm	700 mm
Propellers	15" Carbon Fiber	1555 Carbon Fiber	18" Foldable	14" Carbon Fiber
Longest Flight Time	12 min	71 min	<b>140 min</b>	98 min

	A	B
<b>Solar Module Power</b>	235 W	266 W
<b>Total Voltage</b>	5s (20V)	6s (24V)
<b>Frame Weight</b>	1330 gw	
<b>Solar Cell Pieces</b>	76	86
<b>Solar Module Weight</b>	905 gw	1024 gw
<b>Total Weight (w/o battery)</b>	2235 gw	2354 gw
<b>Frame Size</b>	1600 mm	
<b>Propellers</b>	18"	

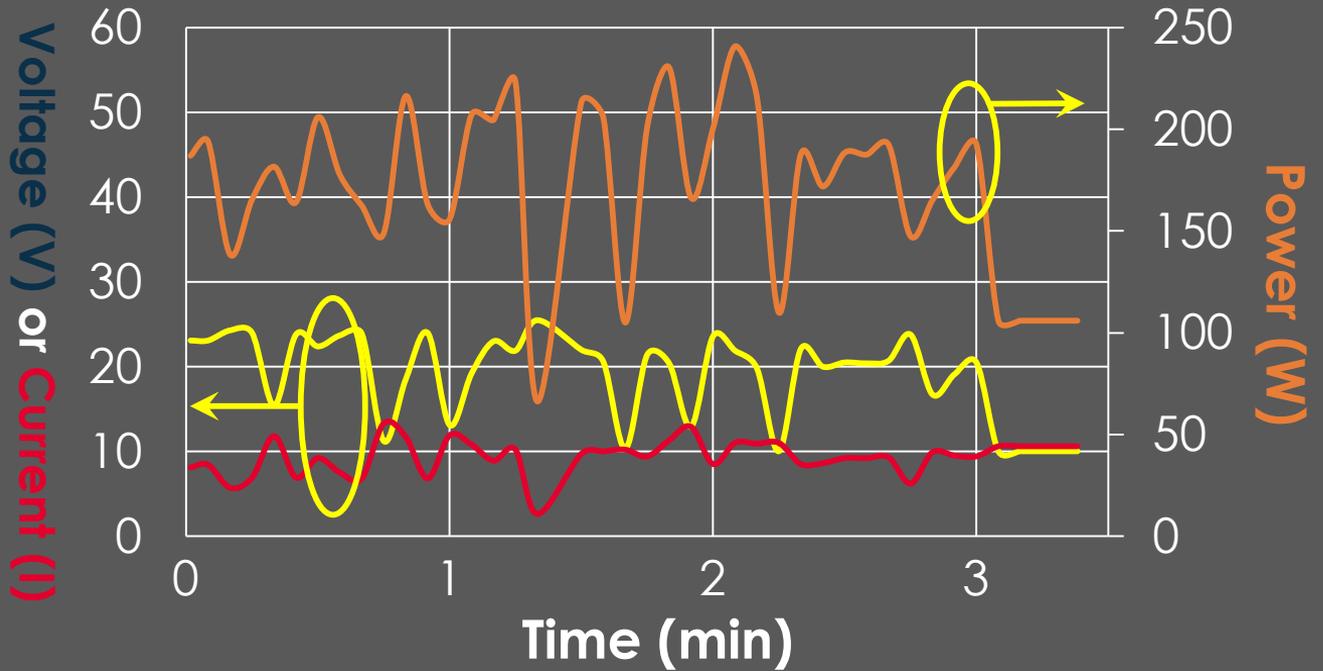
# FLIGHT TIME

	A-1	A-2	A-3
Solar Cell Pieces	76	76	76
Battery	5s 350 mAh (Recharge: 179 mAh)	18350 5s1p 1500 mAh (Recharge: 977 mAh)	J: 5s2p 6.4Ah
Battery Weight	62.5 gw	148.5 gw	517 gw
Flight Time with Hybrid Power	1 hr 1 min 13 sec	<b>2 hr 0 min 14 sec</b>	<b>2 hr 25 min</b>

	B-1	B-2	B-3
<b>Solar Cell Pieces</b>	86	86	86
<b>Battery</b>	H: 6s 1040mAh	I: 6s 260mAh	K: 18350, 6s1p 881mAh
<b>Battery Weight</b>	200 gw	98 gw	168 gw
<b>Flight Time with Hybrid Power</b>	2 hr 4 min 40 sec	1 hr 20 min 6 sec	<b>3 hr 28 min 41 sec</b>
<b>Flight Time with Battery Only</b>	7 min 56 sec	2 min 56 sec	4 min 17 sec
<b>Factor of Extension</b>	15.7	27.3	<b>48.7</b>
<b>Remark</b>	cloud comes at around 115 min	cloud comes at around 75 min	sunlight 94,000 ~ 101,000 Acc. charge: 34200mAh lux

# DISCUSSION

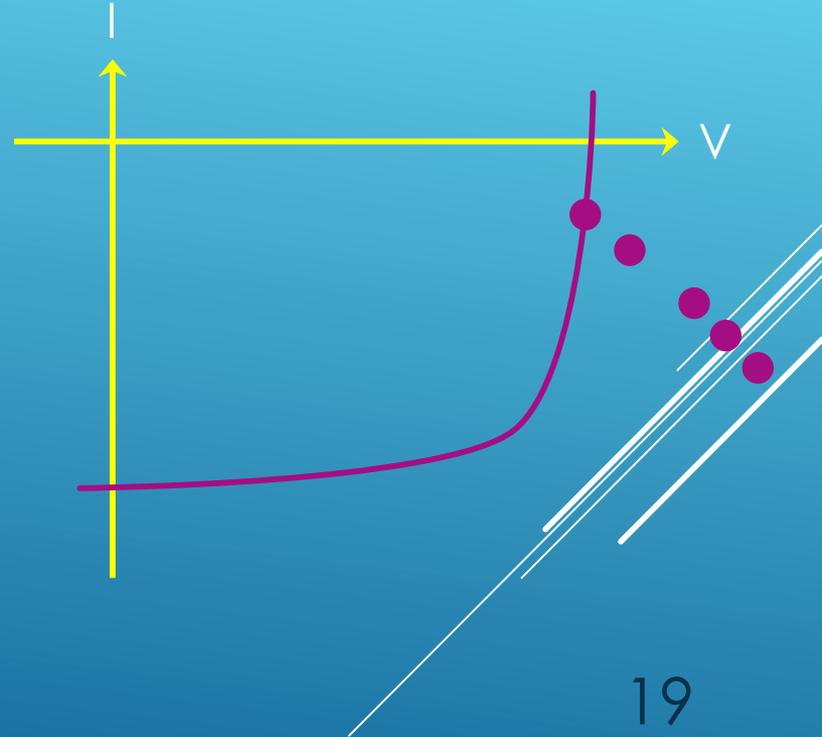
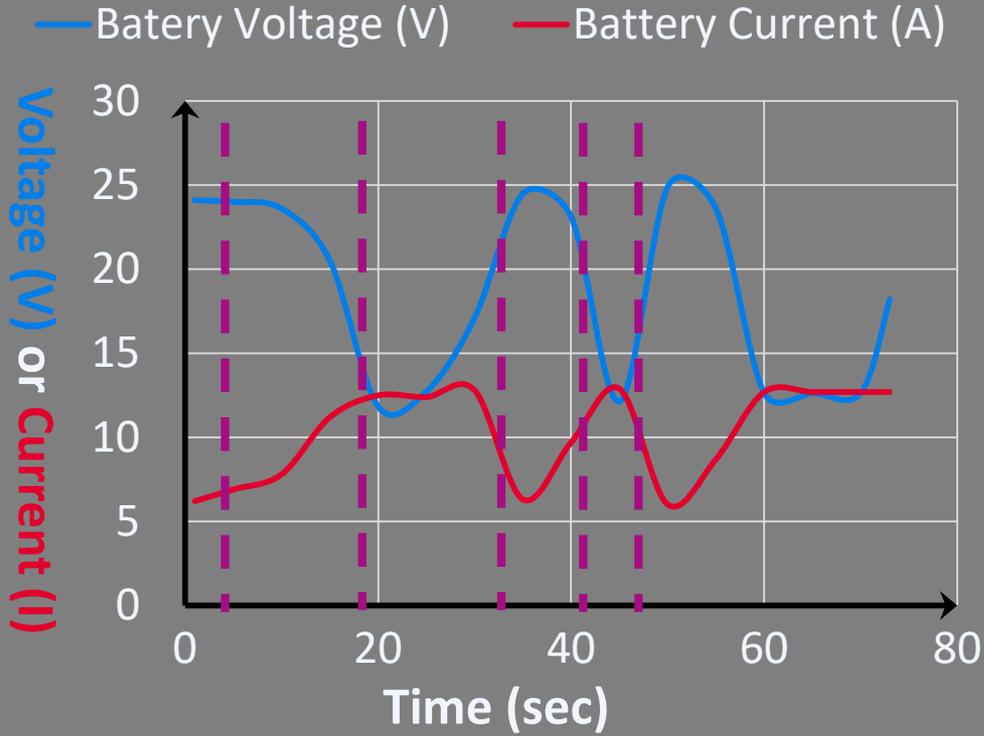
— Battery Voltage (V) — Battery Current (A) — Power (W)



## ► Only Solar

- Voltage, current, & power fluctuate because the drone attitudes change all the time and additional current is required to bring it back to balance.
- Burn out power module.

# DISCUSSION



## Solar + Battery

- ▶ Voltage **stable**.
- ▶ The solar cells are biased by the external voltage supplied by the battery.
- ▶ Current supplied by the solar module is then also fixed.
- ▶ The total current/power still fluctuates but is balanced by the battery.

DISCUSSION

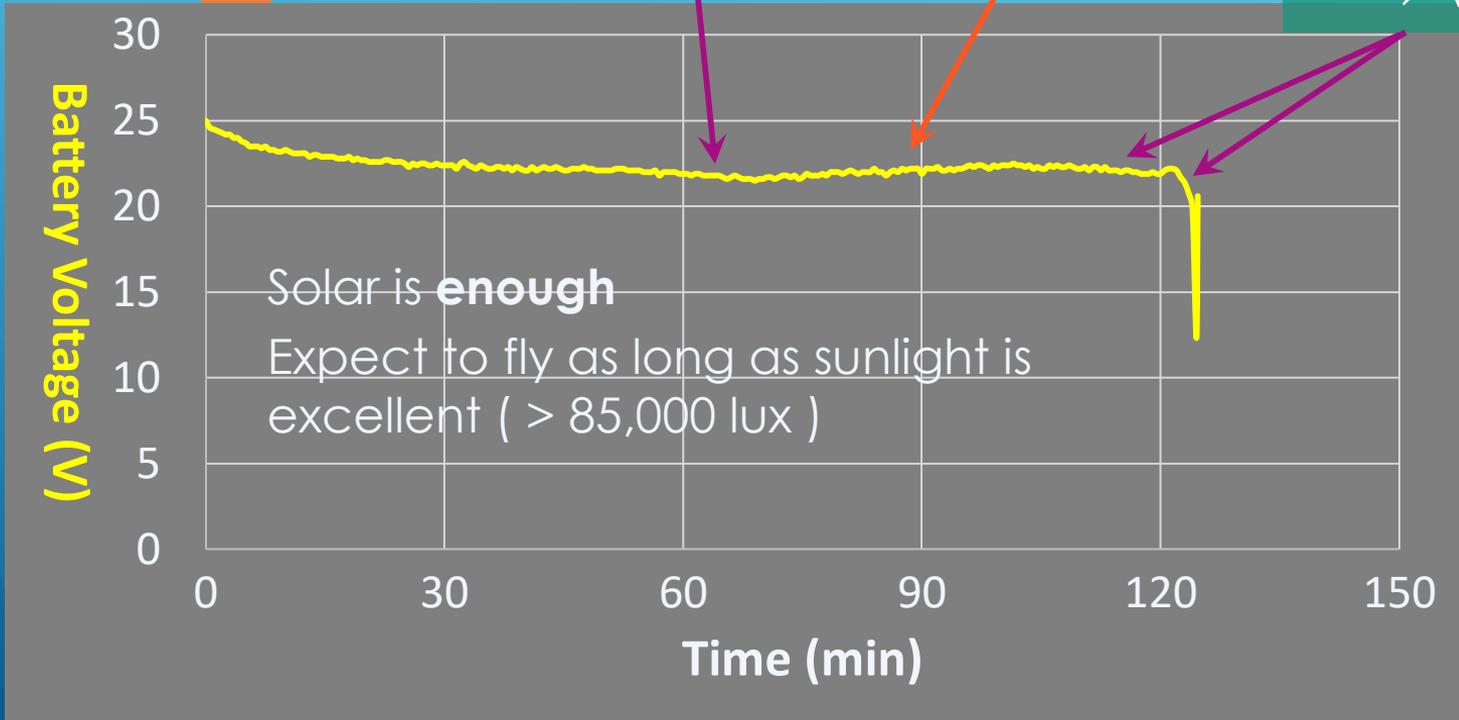
# DISCUSSION

▶ Battery **H**

Cloud  
⇒ V↓

Sunlight  
⇒ V↑

Cloud  
⇒ V↓

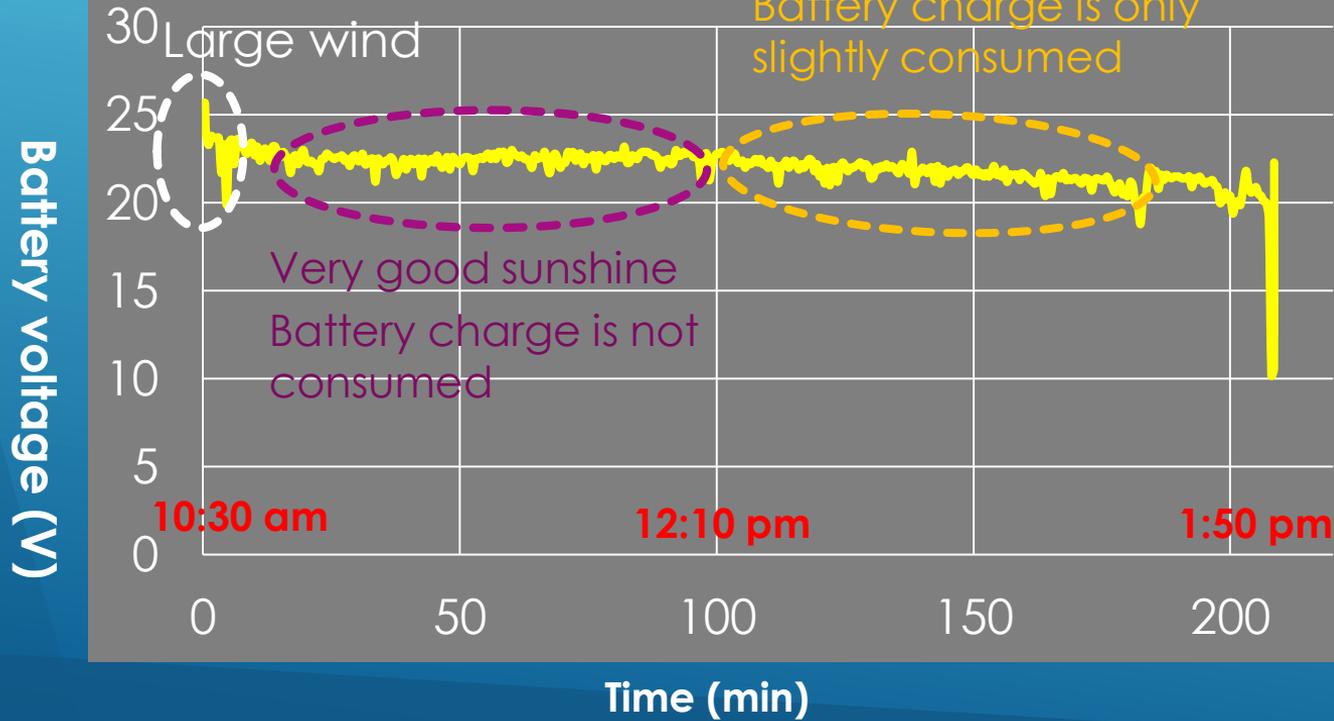


# DISCUSSION

▶ Battery K (6s1p 881mAh)

Sunshine is OK

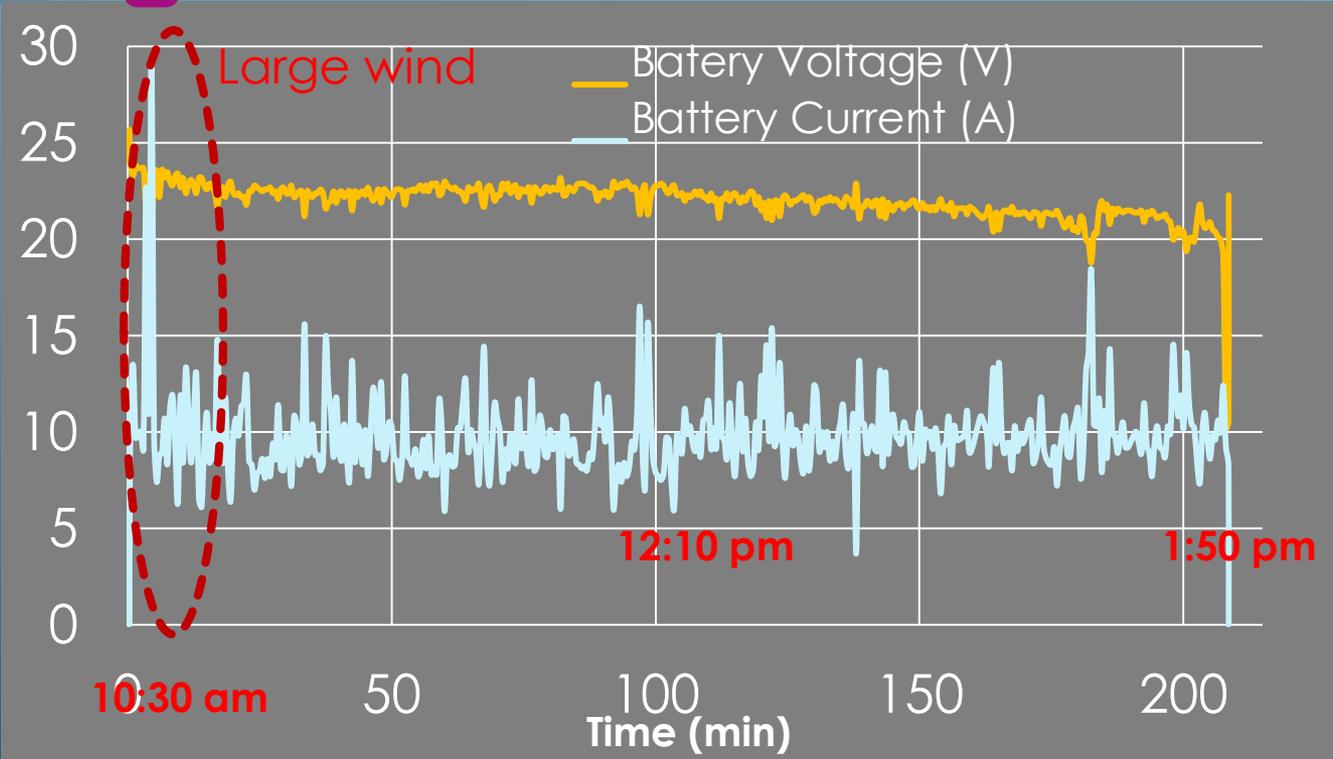
Battery charge is only slightly consumed



# DISCUSSION

▶ Battery K (6s1p 881mAh)

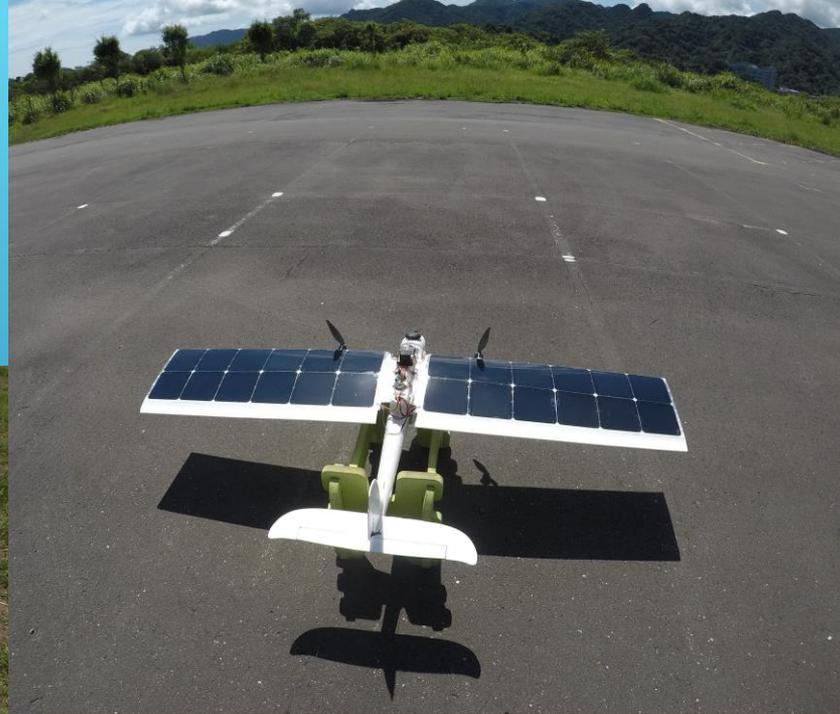
Battery voltage (V)



VIDEO: : 3 HOURS 28 MINUTES



# SOLAR FIXED WING



# SOLAR FIXED WING



# SOLAR FIXED WING



# SOLAR FIXED WING

飛190分鐘的無人機規格：

機身長90cm

機翼長166cm寬31cm

機身重1305g（不含鋰電池）

鋰電池重300g，電壓11.1v，電量5000mah

太陽能電池片數24片

飛行模式 rtl

高度100m

半徑220m

單單鋰電池大約40分+-5分

# SOLAR FIXED WING



# SOLAR FIXED WING

飛203分鐘的規格

翼展192cm

機身1397 g

電池383g

太陽能電池片數目28片

飛行模式 rtl

高度100m

半徑220m

Lghg2 18650 4s2p

單單18650電池大約45分+-5分

# SOLAR FIXED WING



## ADVANCED SCIENCE

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### Solar Power Can Substantially Prolong Maximum Achievable Airtime of Quadcopter Drones

Ching-Fuh Lin , Ta-Jung Lin, Wei-Sheng Liao, Hsiang Lan, Jiun-Yu Lin, Chi-Han Chiu, Aaron Danner

First published: 19 August 2020 | <https://doi.org/10.1002/advs.202001497>

 SECTIONS



PDF



TOOLS



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### Abstract

Sunlight energy is potentially excellent for small drones, which can often operate during daylight hours and fly high enough to avoid cloud blockade. However, the best solar cells provide limited power, compared to conventional power sources, making their use for aerial vehicles difficult to realize, especially in rotorcraft where significant lift ordinarily generated by a wing is already sacrificed for the ability to hover. In recent years, advances in materials (use of carbon-fiber components, improvement in specific solar cells and motors) have finally brought solar rotorcraft within reach. Here, the application is explored through a concise mathematical model of solar rotorcraft based on the limits of solar power generation and motor power consumption. Multiple solar quadcopters based on this model with majority solar power are described. One of them has achieved

[https://onlinelibrary.wiley.com/doi/full/10.1002/advs.202001497?fbclid=IwAR3W6JETx2blh\\_fVGDNhwZApTuJPrsSJDG2z87-8znbboaq4\\_mJZTOlQl6g](https://onlinelibrary.wiley.com/doi/full/10.1002/advs.202001497?fbclid=IwAR3W6JETx2blh_fVGDNhwZApTuJPrsSJDG2z87-8znbboaq4_mJZTOlQl6g)

# 林清富夸父追日 太陽能四軸無人機創最長飛行時間(之一)

黃逸平 2018-12-10

讚 748 分享

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電子時報 DIGITIMES



台灣大學電資學院特聘教授林清富突破太陽能四軸無人機關鍵技術，創下最長飛行時間

今年9月，台灣的太陽能四軸無人機(Quadcopter)創下飛行3小時28分鐘的世界紀錄，推手是台灣大學電資學院吳瑞北和林清富兩位特聘教授。吳瑞北負責尋找研發資源，而林清富因數年前栽入無人機世界，開始動手研發電力結構與太陽能模組，從業餘玩家晉身專家，最後在自己的家鄉宜蘭創下紀錄，無疑是個人嗜好結合專長發揚光大的最佳範例。

# US NEWS REPORT

<https://www.suasnews.com/2017/12/solardrone-ntu-allowing-drones-explore-unexplored-frontiers-launches-ces-2018/>

安全 | <https://www.suasnews.com/2017/12/solardrone-ntu-allowing-drones-explore-unexplored-frontiers-launches-ces-2018/> ☆

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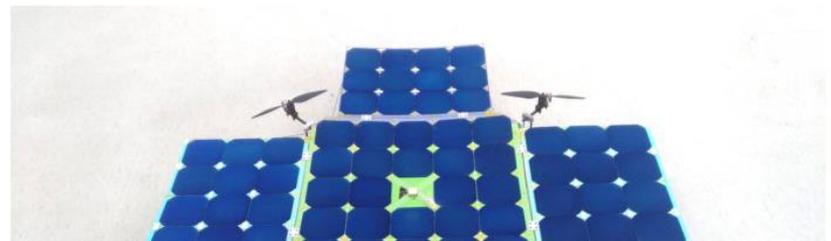


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## SolarDrone (NTU), Allowing Drones to Explore Unexplored Frontiers Launches at CES 2018

By **Press** - 29 December 2017



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# JAPANESE NEWS REPORT

<https://www.amw.jp/2017/12/31/201712311/>



安全 | <https://www.amw.jp/2017/12/31/201712311/>

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ホーム > ドローン > SolarDrone - 飛行時間を増やすためのソーラーパネルを備えたドローン

## SolarDrone - 飛行時間を増やすためのソーラーパネルを備えたドローン

2017年12月31日

ソーラードローンは、太陽光発電やUAV技術の専門家と協力して国立台湾大学の研究室から設立されたスタートアップ企業で、ドローンの限られた飛行時間を克服しています。ソーラーパネルを搭載したドローンがCES 2018に展示される予定です。

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### SolarDroneの折り畳み式ソーラードローン

ソーラードローンの無人航空機は、天候や日の出条件にもよりますが、一般的には30分以内の飛行時間が数時間程度を約束しています。これらの高い目標を達成するために、設計チームは、できるだけ大きな太陽電池パネル面積を可能にするために、非常に大きな表面を備えた非常に軽量のクワドコプターを開発するよう努めました。

#### 人気の記事

- Amazonビデオが無料でみれる！
- amazonプライム  
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- シグナルプライベートメッセージングとは - シグナルアプリケーションの使い方
- DJI SparkとiPhoneの接続で問題？修正する方法
- 2018年、おすすめAndroid用スマートウォッチ
- iPadがマルチアカウント対応する噂
- OnePlus 5のディスプレイを上下逆さまにすると「ゼリースクロール」の問題が発生!?
- Googleが便利な「画像の表示」ボタンをGoogleイメージ検索から削除！

# CHINESE NEWS REPORT

<http://www.yuchen360.cn/news/16524-0-0.html>

The screenshot shows the Yuchen Aerospace website interface. At the top left is the logo with the text "宇辰 AEROSPACE" and "读懂无人机 返回旧版". A search bar contains the placeholder text "输入您想搜索的关键词". A navigation menu includes "首页", "资讯", "测评", "专题", "活动", "电商", "专家专栏", and "投稿申请". The article title is "2018年CES倒计时 | 无人机能否再成亮点?". The source is "来源: 宇辰网" and the author is "作者: 陈莹". A QR code is provided for WeChat, with the text "关注宇辰官方微信 实时掌控业界最新动态". A section titled "每周十大热门文章" is also visible.

## SolarDrone

展位: Sands, Hall G – 52105

介绍: 来自台湾大学的新兴团队SolarDrone正联合光伏和无人机技术专家来解决无人机十分受限飞行时长问题。该团队将携太阳能动力无人机在CES上亮相, 据悉经改良的无人机拥有更轻机身和更长续航能力。



# CONCLUSION-SOLAR QUADCOPTER

- ◆ **Solar hybrid energy systems are developed for quadcopters.**
- ◆ The backup battery and the sunlight have a significant impact on the flight time.
- ◆ Stable sunlight should allow the quadcopter to fly well for hours.
- ◆ **Longest flight time: 3 hr 28 min**; flight time extended to **over 48 times** of using battery only (18350 6s1p, 881mAh, 168 gw).
- ◆ **The accumulated charge from solar modules is 34200mAh, ~ 3kg battery, too heavy for the copter to lift.**



# CONCLUSION-SOLAR FIXED WING

- ◆ Wing span < 2 m (192 cm)
  - ◆ the smallest fixed wing to fly hours using sunlight
- ◆ Longest flight time: 3 hr 23 min
  - ◆ Flew on Nov. 18, 2020, winter time, expected to be much longer in summer.
- ◆ 28 Solar cells (CF: 86 cells for quadcopter)
- ◆ Accumulated charge 17.9 Ah
- ◆ Power required is much less than quadcopter



# ACKNOWLEDGEMENT

We would like to acknowledge the financial supports from

- (1) the project in National Taiwan University with the number of 06HT911001.
- (2) Ministry of Science and Technology with numbers of MOST 108-3116-F-002-009 -CC2 and MOST 108-3116-F-002-010 -CC2.

# THANK YOU FOR YOUR ATTENTION

Emails: [lincf@ntu.edu.tw](mailto:lincf@ntu.edu.tw)

