드론의 개요

Professor H.J. Park, Dept. of Mechanical System Design, Seoul National University of Science and Technology.

An Unmanned aerial vehicle (UAV) is a Unmanned Aerial Vehicle. UAVs include both autonomous (means they can do it alone) drones and remotely piloted vehicles (RPVs).

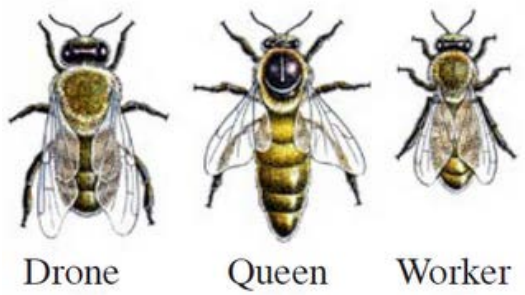
CONTENTS

드론이란 무엇인가?

Drone 의 어원

- **정의**:
  - 영어 고어 **Drone** = male bee = lazy people
- 역사
  - ~1900: Kite, balloon
  - 1차 세계대전 중 무선조종 비행기 개발
  - 1935: 영국해군 DH 82B Queen Bee
  - 1939: Radioplane → Drone

정찰 및 대공무기의 Target으로 활용됨.



http://blogs.evergreen.edu/terroir-zack/life-cycle-of-the-honey-bee/

https://commons.wikimedia.org/w/index.php?curid=30910654

영국 DH 82B “Queen Bee”

미국 Radioplane - QQ-3

http://www.ctie.monash.edu.au/hargrave/rpav_radioplane4.html

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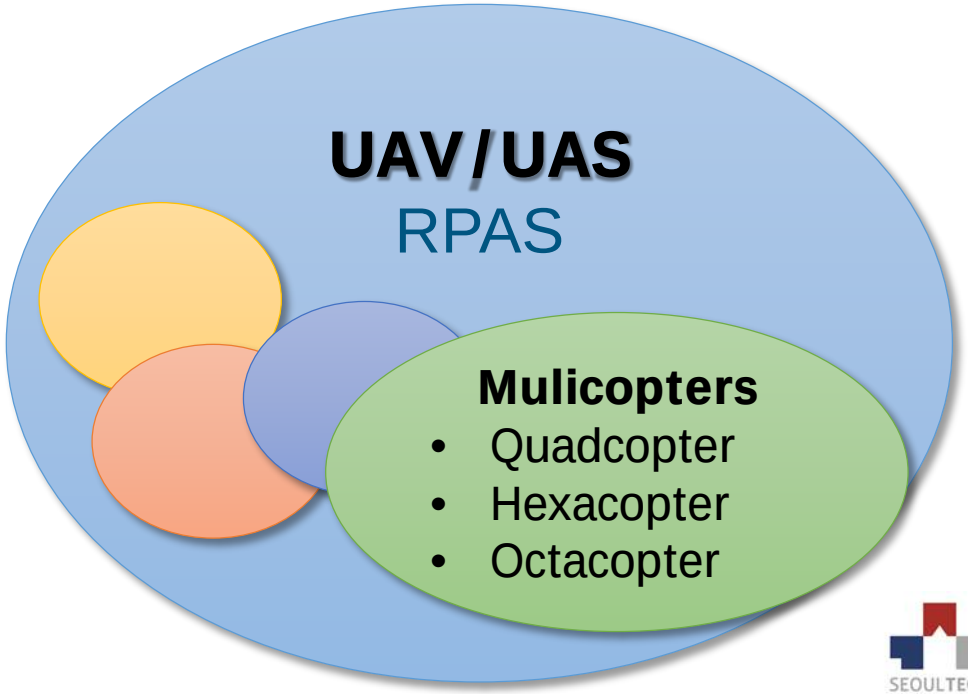
공식명칭

Official Names

- **UAV**
  - Unmanned Aerial Vehicle
- **UAS**
  - Unmanned Aerial System
  - 연방항공국(FAA) 공식이름
- **RPAS**
  - Remotely Piloted Aircraft Systems -

http://www.avinc.com/media_center/unmanned-aircraft-systems/raven



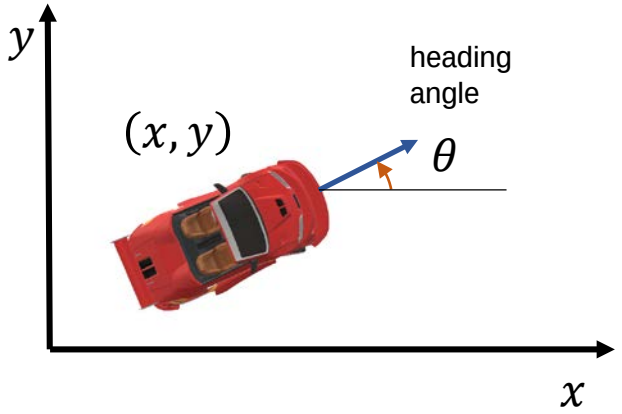
2차원 평면 운동 - 차량, 선박

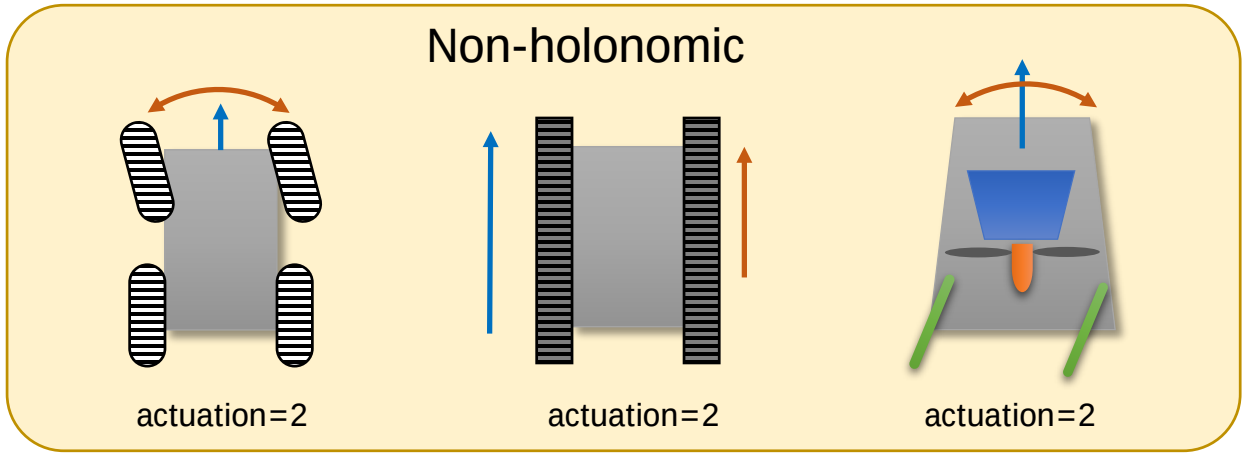
Dept. of Mechanical System Design, Seoul National University of Science and Technology.

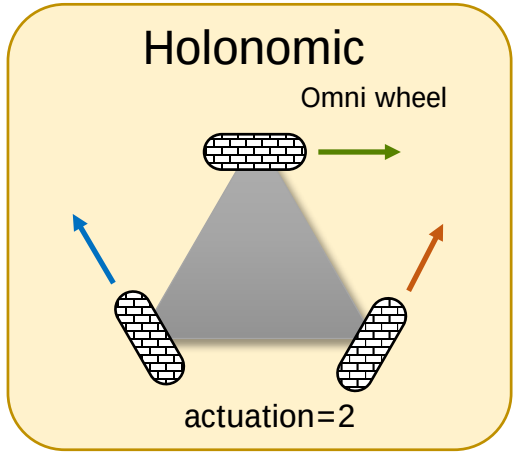
- 2D상의 운동체의 상태
  - 위치 (x, y)와 방향각 θ로 결정
  - 3개의 구동으로 위치/방향각을 임의로 결정

  → Holonomic (구동수 = 상태수)

  → Non-holonomic (구동수 < 상태수)
- 2D상의 상태 결정 방법



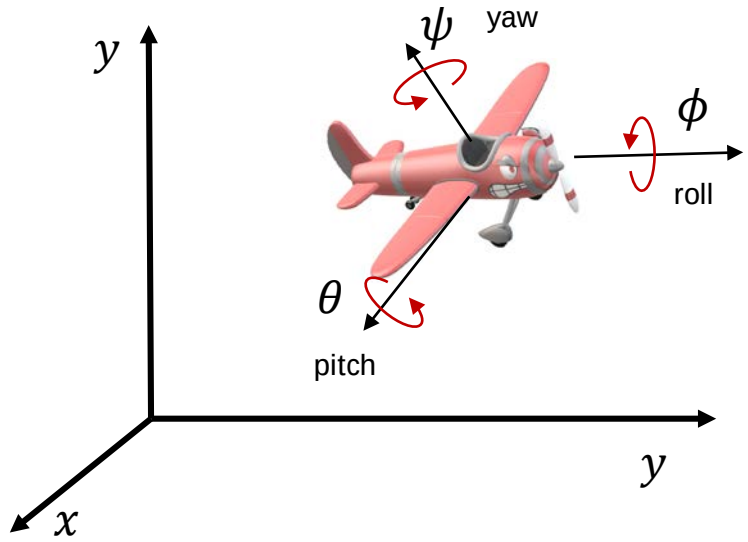




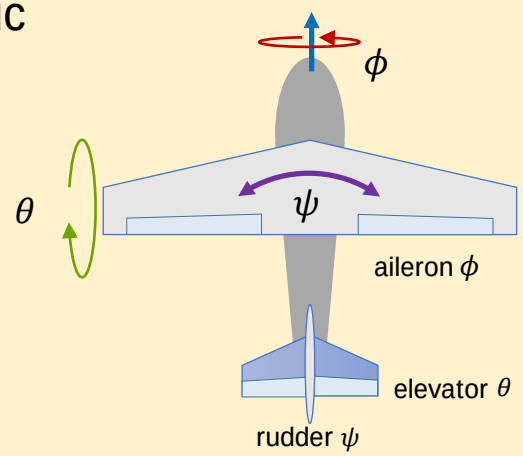
3차원 공간운동 - 비행체, 잠수함

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 3D 공간상의 비행체 상태
  - 위치 (x, y, z), 자세(ϕ, θ, ψ)로 결정
  - 6개의 구동으로 6개의 위치/자세를 임의로 결정
    → Holonmic
- 상태 결정 방법



Non-holonomic



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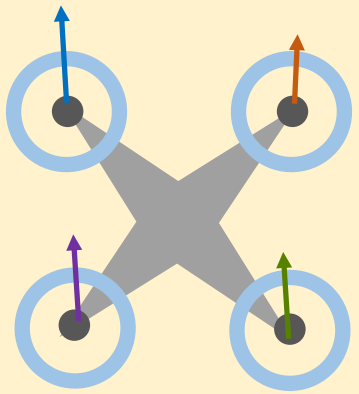


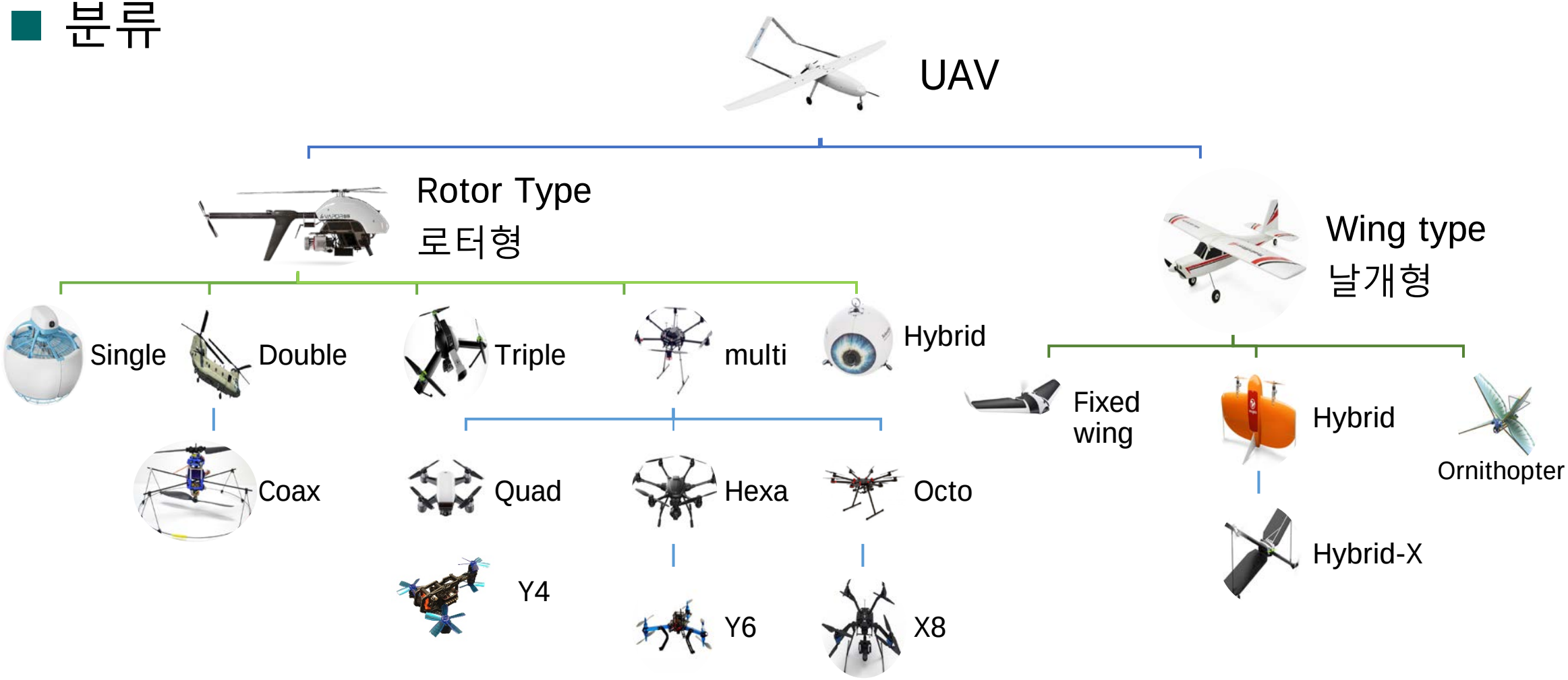
actuation=4

actuation=4

드론의 분류

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

분류



드론의 분류: 로터형

로터형

Rotor Type
로터형

Single
싱글 로터

Double
더블 로터

Triple
트리플 로터

multi
멀티 로터

Coax
동축 로터

Quad
4

Hexa
6

Octo
8

Y4

Y6

X8

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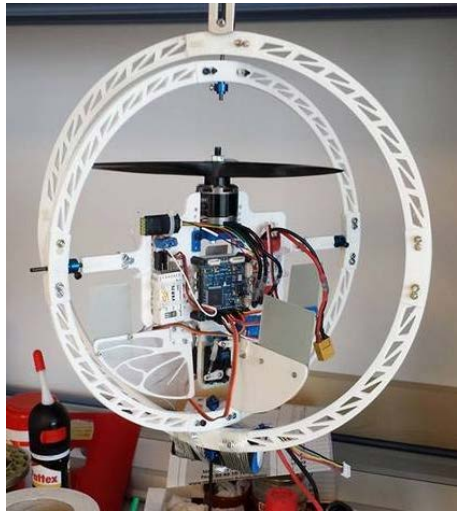
로터형: 싱글로터

싱글로터 로터

swash plate



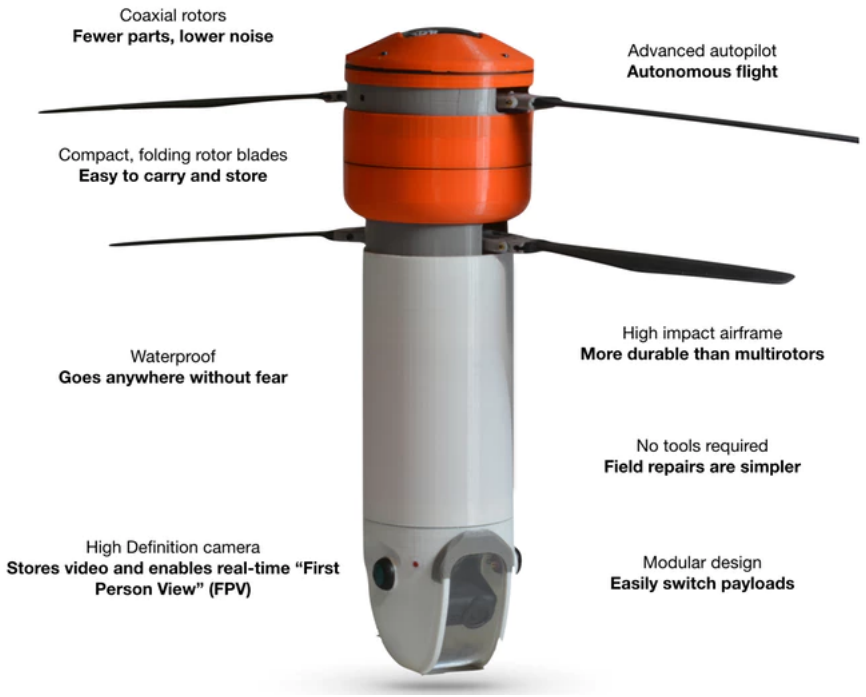
플랩사용

로터형: 더블 로터

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 동축 로터
  - 2개의 로터와 스와시 플레이트 또는 가변축 사용

swash plate



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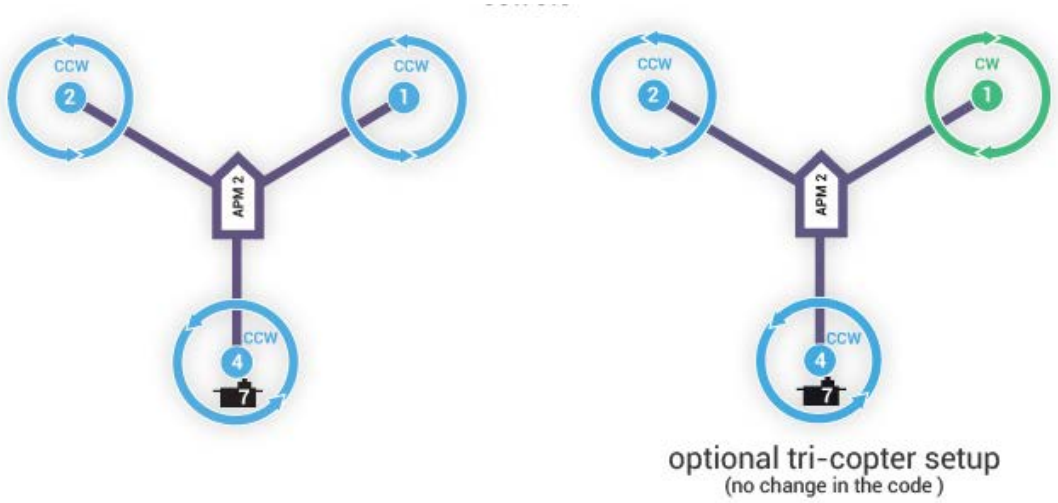
로터형: 동축로터

- 2개의 로터+ 4개의 플랩

로터형: 트라이로터

- 3개의 로터와 1개의 가변축 사용



로터형: 풍선 하이브리드

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 로터형과 풍선의 조합

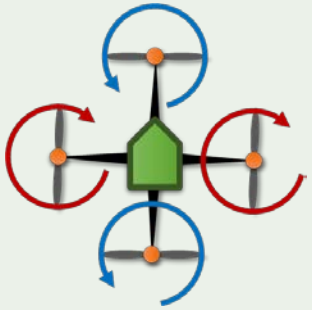
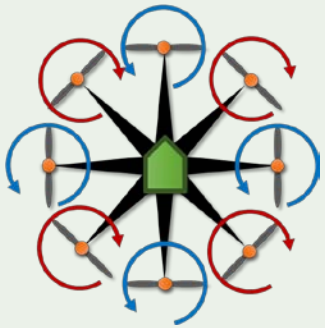
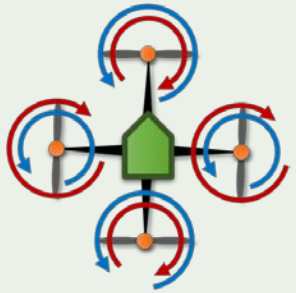
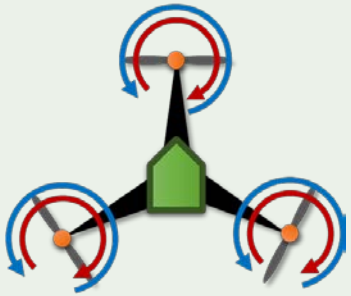
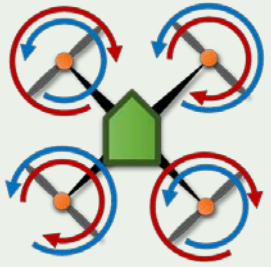
actuation=6

Holonomic!

공식 Multi-copter

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 로터의 수는 주로 짝수개
  - 수직 회전의 반작용 상쇄를 서로 다른 회전 방향

Quad	Hexa		Octo	
				
+	+	Y	+	Y
				
X	V	IY	X	IY

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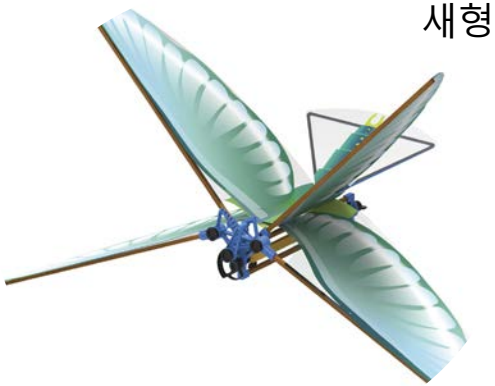
드론의 분류

- Wing형

Wing type
날개형

Ornithopter
새형



Fixed wing
고정날개

Hybrid
하이브리드

Hybrid-X
하이브리드 -X

SEOULTECH

날개형: 하이브리드

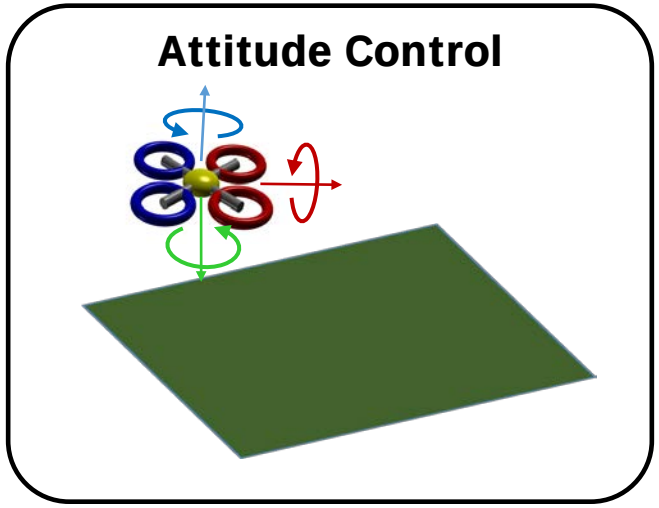
- 하이브리드: 날개형과 로터형의 조합

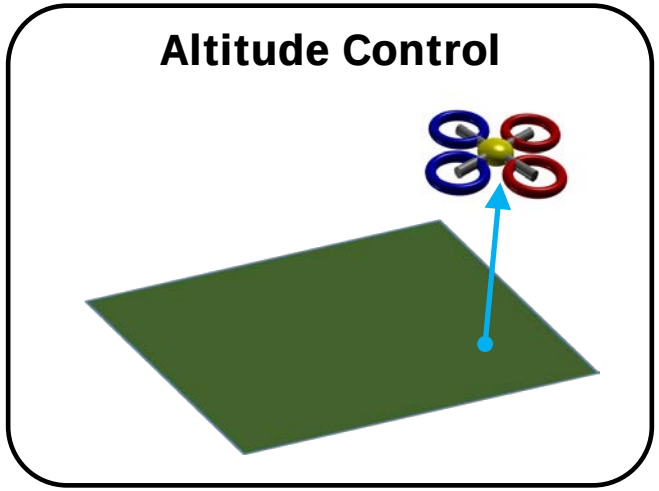
Quadrotor 제어원리

Quadrotor 제어 목표

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 기본 제어
  - 자세 (Attitude) 제어
    - 요구사항: 원하는 자세를 취할 것. (roll, pitch, yaw)
    - 자세 측정이 필요
      - IMU, AHRS
  - 고도 (Altitude) 제어
    - 요구사항: 원하는 고도를 유지할 것
    - 고도 측정이 필요
      - 압력센서(Barometer)
      - GPS
      - 초음파 센서 (Ultrasonic)
      - Lidar

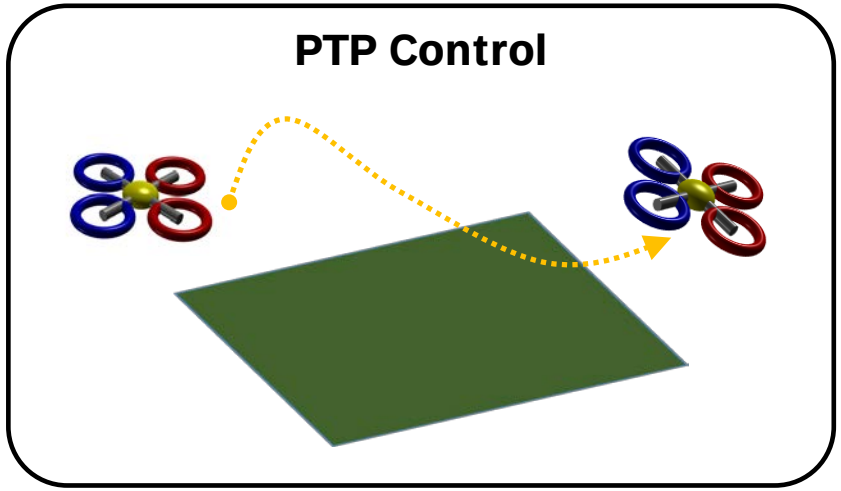


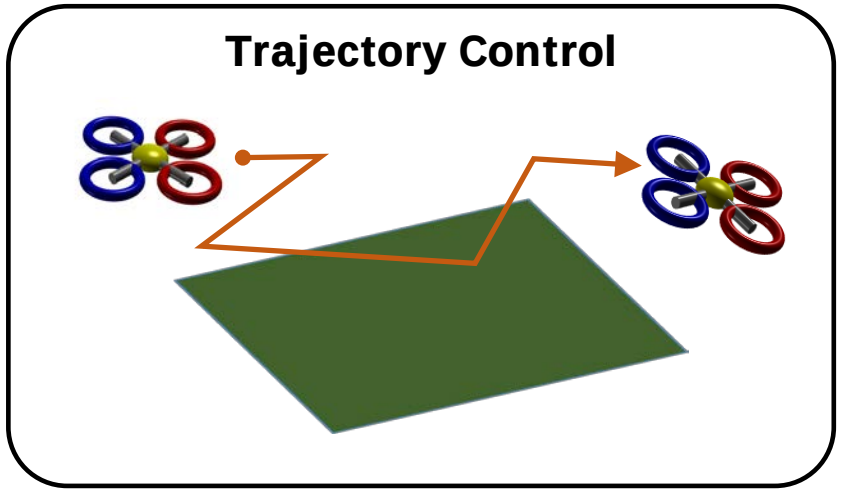


Quadrotor 제어 목표

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 고급 제어
  - PTP(Point to Point) 제어
    - 요구사항: 경로에 무관하게 원하는 지점으로 이동할 것.
    - GPS 등 절대위치 센서 필요
  - 경로 (Trajectory) 제어
    - 요구사항: 원하는 경로를 따라 움직일 것
    - GPS 등 절대위치 센서 필요
    - 절대위치 기준 경로 데이터 필요

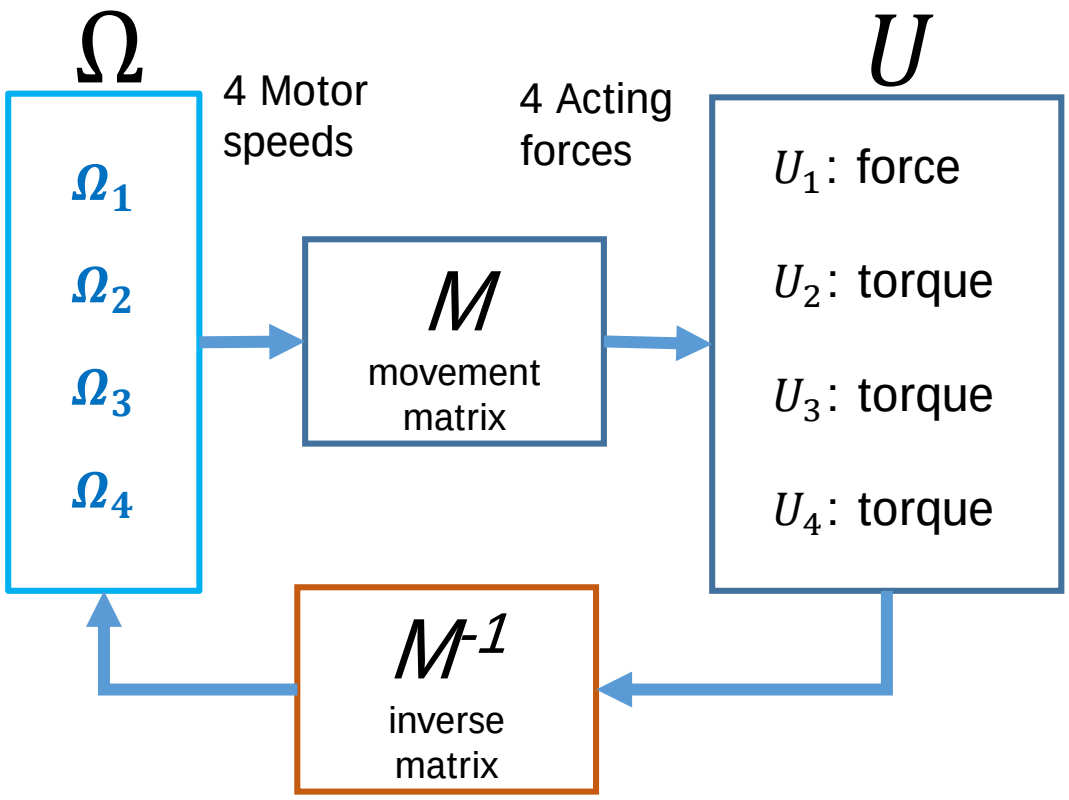




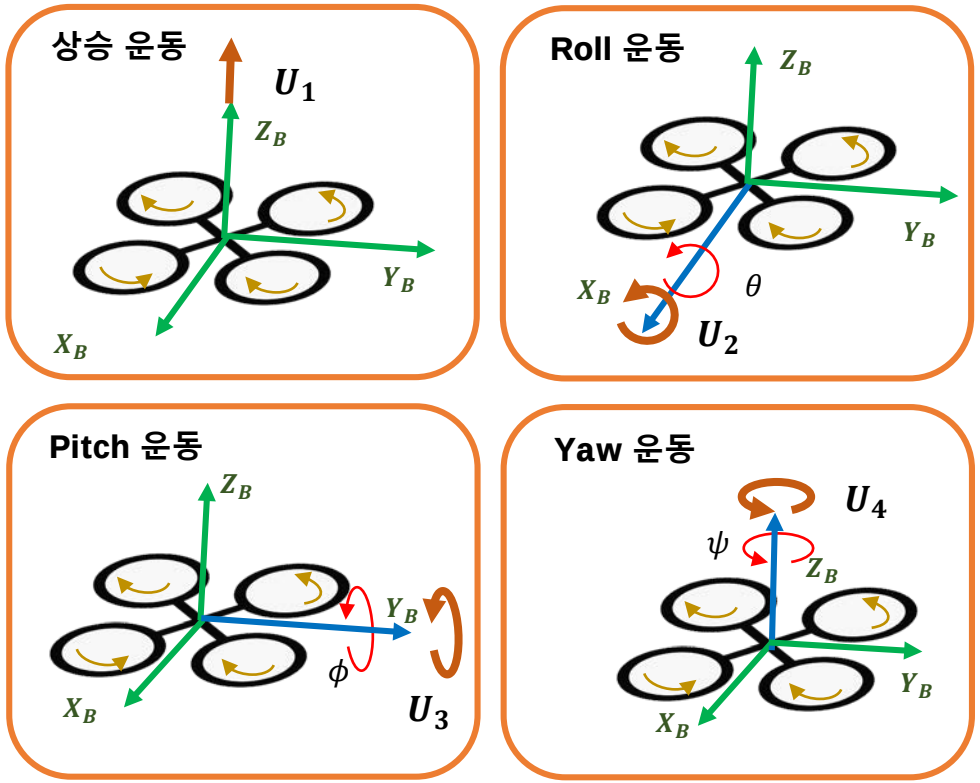
Quadrotor 제어방식

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 4개의 **프로펠러 회전속도** ➔ 4개의 **작용력** ➔ 4개의 **운동**



4개의 운동

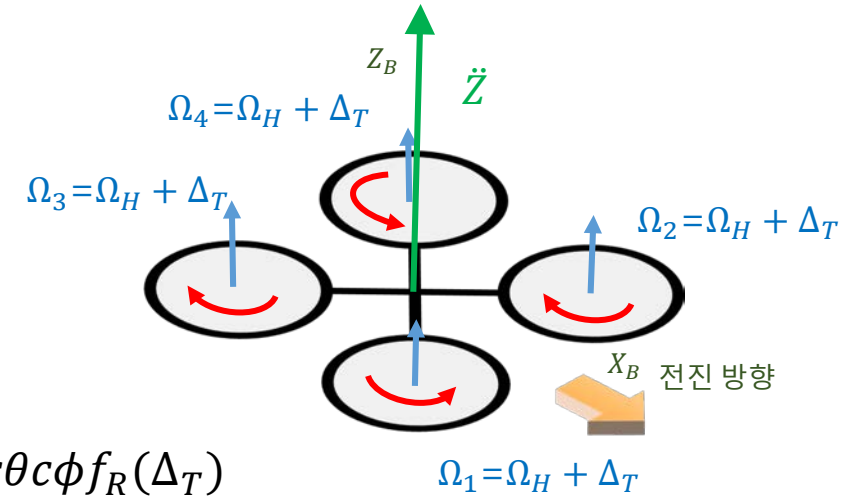


Quadrotor 제어방식

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

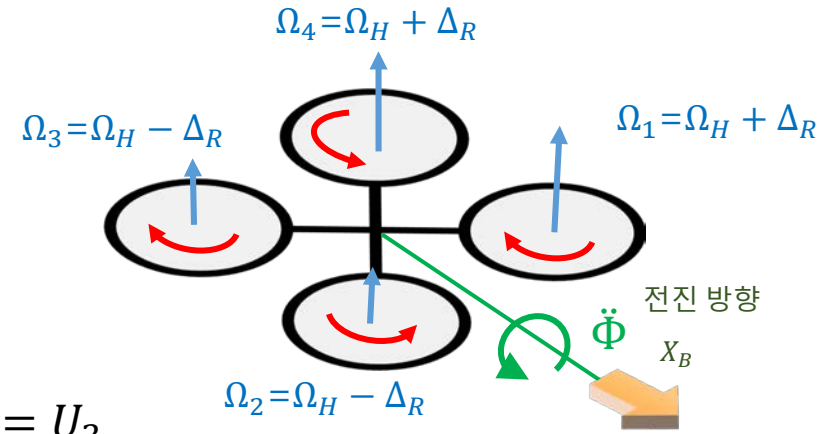
- U_1 **Throttle** 제어: Z_B방향의 가속 $\ddot{Z}$
  - 기본 Hovering+Δ_T
    - $\Omega_1 = \Omega_H + \Delta_T$:
    - $\Omega_2 = \Omega_H + \Delta_T$:
    - $\Omega_3 = \Omega_H + \Delta_T$:
    - $\Omega_4 = \Omega_H + \Delta_T$:
  - $\sum_i \Omega_i = 4(\Omega_H + \Delta_T)$

Ω_H: 기본 호버링에 필요한 회전속도



$$m\ddot{Z} = -mg + c\theta c\phi f_R(\Delta_T)$$
$$= -mg + c\theta c\phi U_1$$

- U_2 **Roll 제어**: X_B방향의 회전가속 $\ddot{\Phi}$
  - $\Omega_1 = \Omega_H + \Delta_R$:
  - $\Omega_2 = \Omega_H - \Delta_R$:
  - $\Omega_3 = \Omega_H - \Delta_R$:
  - $\Omega_4 = \Omega_H + \Delta_R$:
  - $\sum_i \Omega_i = 4\Omega_H$

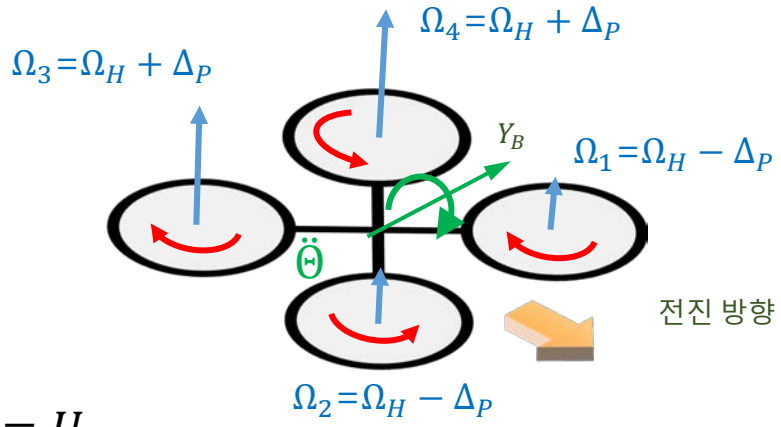


$$I_{xx}\ddot{\Phi} = 4\ell f_R(\Delta_R) = U_2$$

Quadrotor 제어방식

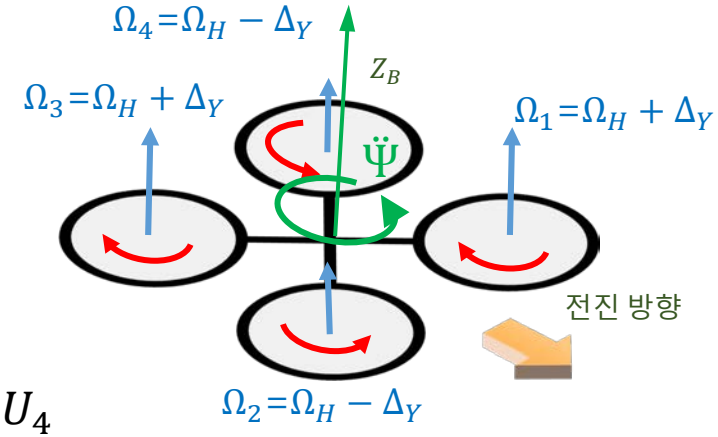
Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- U_3 **Pitch 제어**: Y_B방향의 회전가속 $\ddot{\Theta}$
  - 기본 Hovering+Δ_P
    - $\Omega_1 = \Omega_H - \Delta_P$:
    - $\Omega_2 = \Omega_H - \Delta_P$:
    - $\Omega_3 = \Omega_H + \Delta_P$:
    - $\Omega_4 = \Omega_H + \Delta_P$:
  - $\sum_i \Omega_i = 4\Omega_H$



$$I_{yy}\ddot{\Theta} = 4\ell f_P(\Delta_P) = U_3$$

- U_4 **Yaw 제어**: Z_B방향의 회전가속 $\ddot{\Psi}$
  - $\Omega_1 = \Omega_H + \Delta_Y$:
  - $\Omega_2 = \Omega_H - \Delta_Y$:
  - $\Omega_3 = \Omega_H + \Delta_Y$:
  - $\Omega_4 = \Omega_H - \Delta_Y$:
  - $\sum_i \Omega_i = 4\Omega_H$

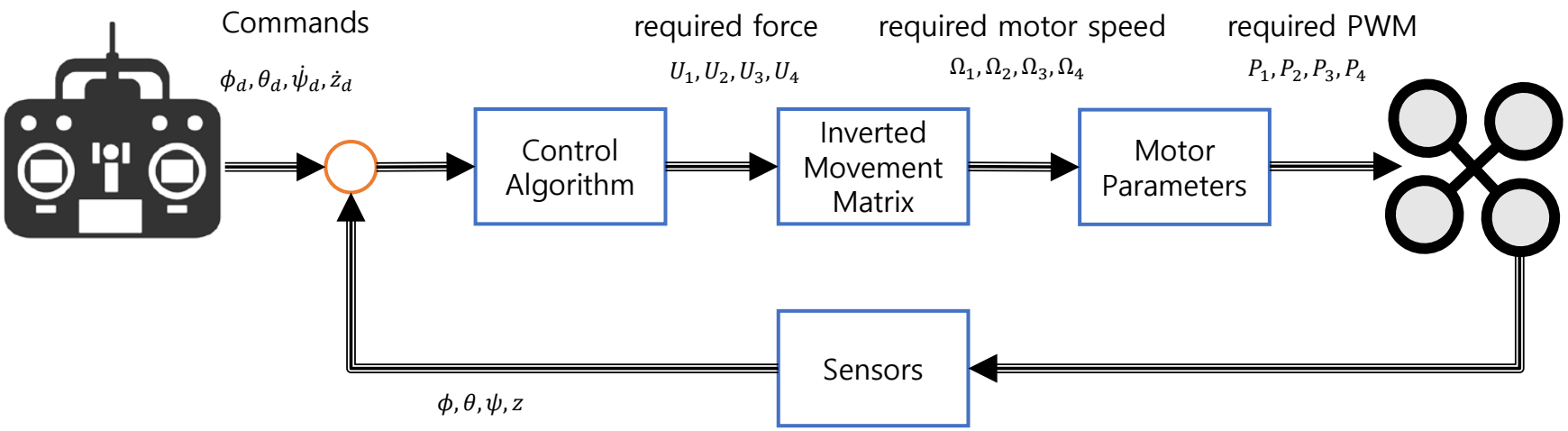


$$I_{zz}\ddot{\Psi} = 4f_Y(\Delta_Y) = U_4$$

Quadrotor 제어시스템

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

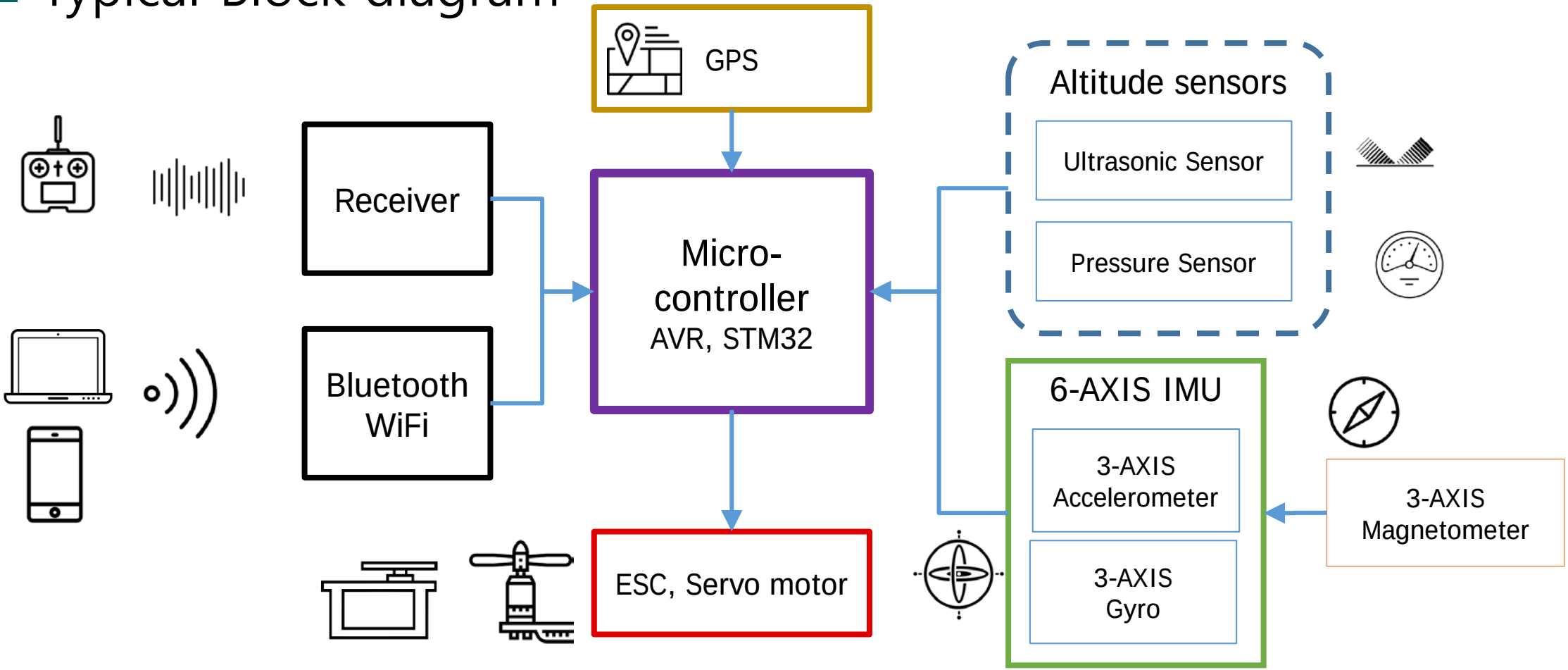
Overall control system diagram



Quadrotor 제어시스템

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

Typical Block diagram



관성항법 시스템

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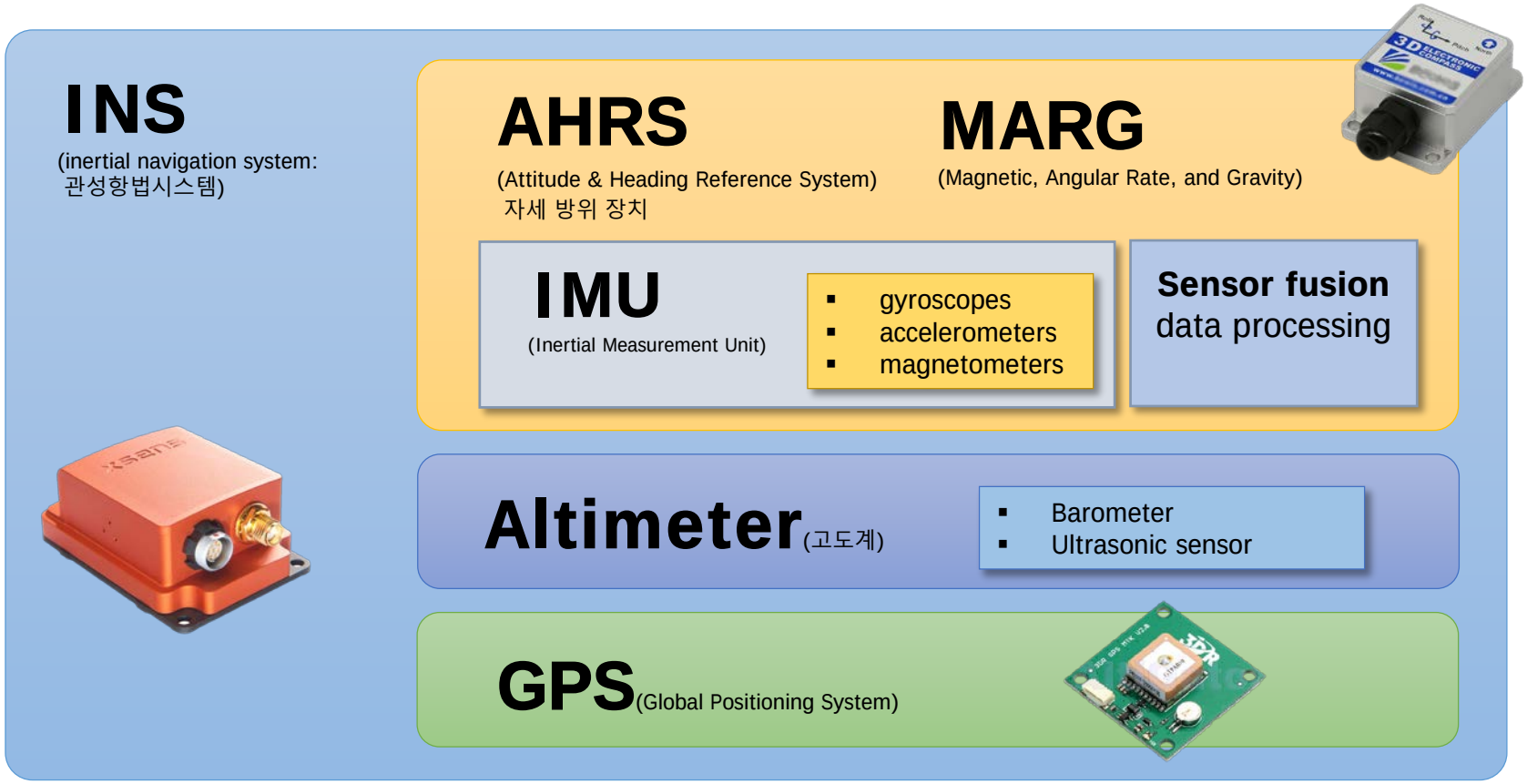
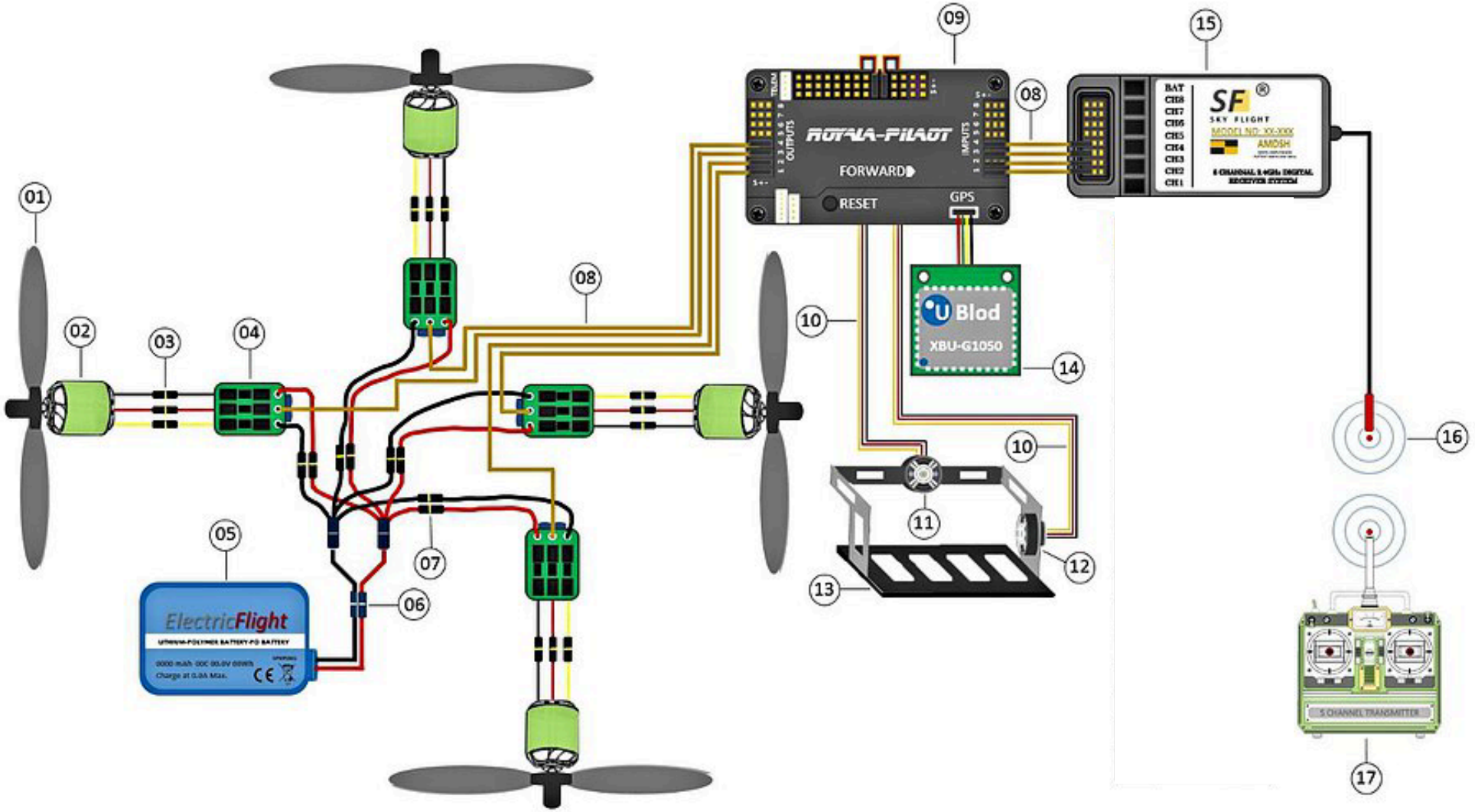
INS, IMU, AHRS, MARG



드론의 구성

Ardupilot Components

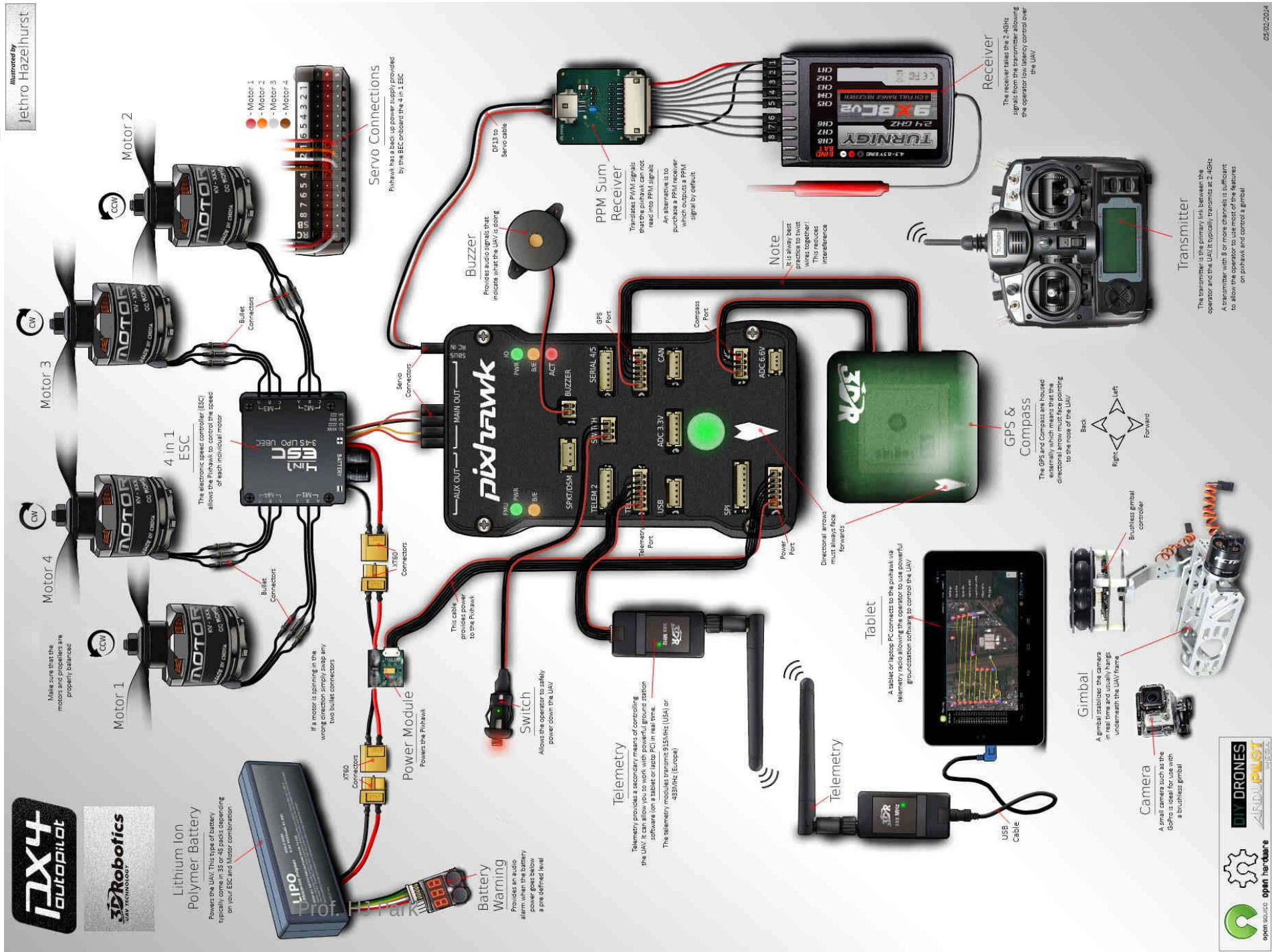


1	Propeller
2	BLDC motor
3	Connectors
4	ESC
5	Li-Po battery
6	Power Distributor
7	
8	Servo connector
9	Flight Controller
10	Gimbal Connector
11	Gimbal - Roll
12	Gimbal - Pitch
13	Gimbal
14	GPS
15	RC receiver
16	2.4GHz Antenna
17	RC Transmitter

PX4

Dept. of Mechanical System Design, Seoul

https://docs.px4.io/en/assembly/quick_start_pixhawk.html

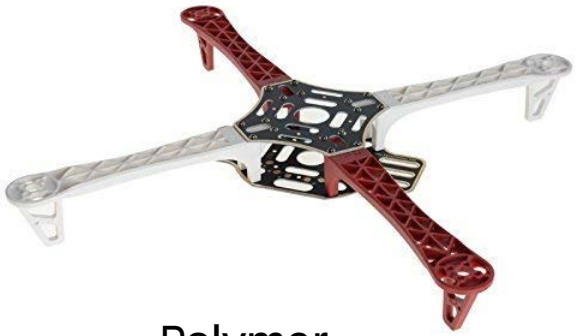


드론의 구성: Quadcopter

- Frame/ Chassis
  - Drone body를 이루며 여러 부품들을 지지한다.
  - 가볍고 튼튼해야 하기 때문에 Carbon fiber plate, Engineering plastic 등을 사용한다.
  - 주로 사양은 대각선 프로펠러의 거리로 표시
    - F450 → 대각선 프로펠러 450mm

Carbon fiber

F450

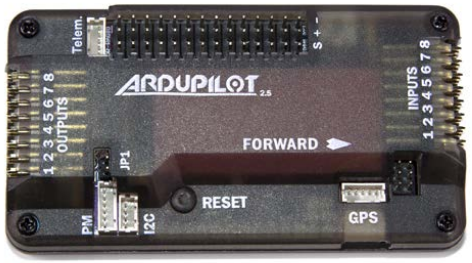


Polymer

드론의 구성: Quadcopter

- FC (Flight Controller)
  - Microcontroller 기반의 주 제어기
  - IMU 센서, 고도 센서, 지자기 센서 등 내장
  - 제어 알고리즘 연산
  - digital 입출력, analog 입력 가능
  - Timer 를 이용한 PWM 출력
  - Timer Capture 기능을 이용한 PWM 복조
  - UART, I2C, SPI 등의 통신 기능
  - 기타 : LED

Crius



Ardupilot

NAZE 32

pixhawk

드론의 구성: Quadcopter

구동모터

- Brushed-DC
  - 소형, 저속, 저토크, 단수명
- Brushless-DC (BLDC)
  - 고속, 고토크, 장수명
  - 제어 어려움
- BLDC 모터의 사양
  - Kv 상수: 무부하 시 volt 당 rpm 수
  - Ex: Kv= 980, 3S 인 Lipo battery 경우
    - 무부하 rpm = 980 x (3x3.7)=10,878 rpm

S rating:
Lipo battery 는 1S당 3.7 Volts가 나온다.

DC-Motor

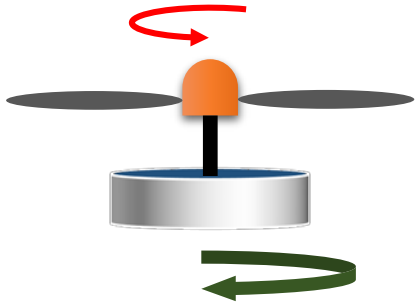
BLDC-Motor

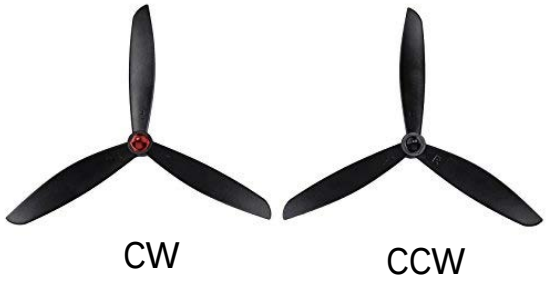
드론의 구성: Quadcopter

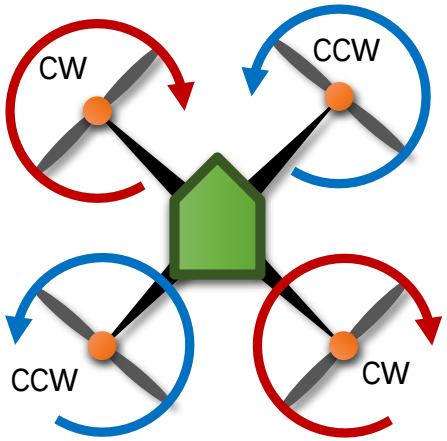
- ESC(Electronic Speed Controller)
  - BLDC 모터 속도제어 모듈을 지칭
  - 주로 사양은 최대전류로 표시
  - 전압은 Cell 수로 표시

드론의 구성: Quadcopter

- 프로펠러
  - 하나의 프로펠러가 회전하면
    - 작용 반작용으로 기체가 yaw 방향으로 따라 회전한다.
  - 이를 상쇄시키려고
    - 반대 방향으로 회전하는 프로펠러를 짝으로 배치한다.





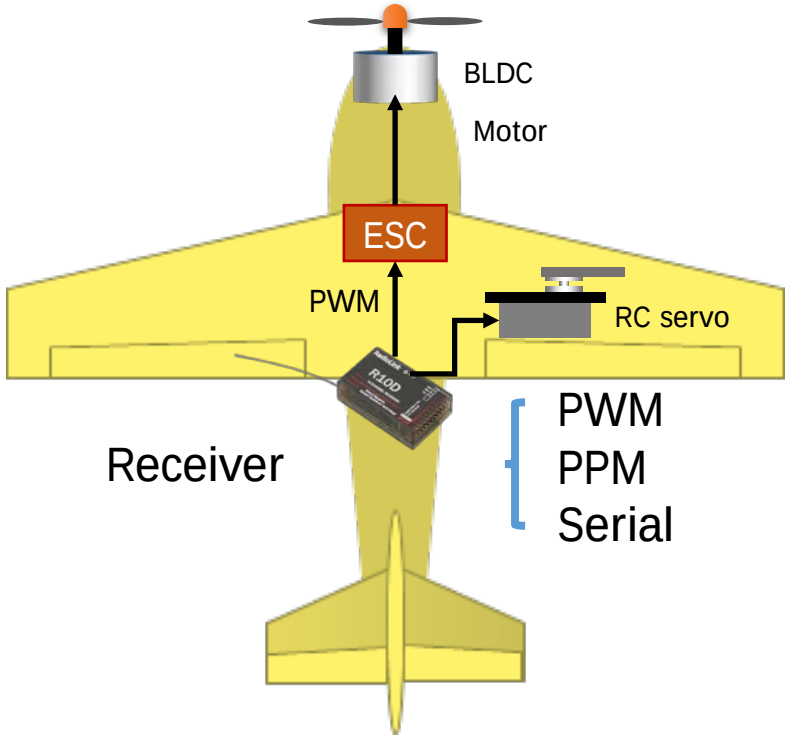


드론의 구성: Quadcopter

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 송수신기
  - 27MHz, 50MHz, 72MHz, 2.4 Hz

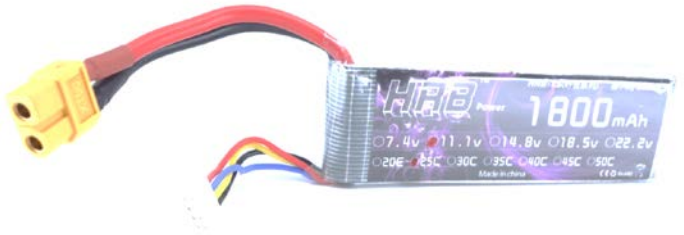
RC Controller



드론의 구성: Quadcopter

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

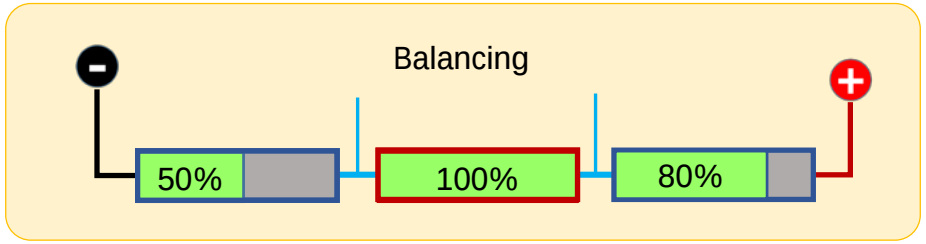
- Battery Pack
  - Li-Po (Lithium polymer) battery
    - 셀수 (Cell count #S)
      - Cell 당 3.7V 를 공급한다. 3S → 3x3.7 =11.1V
    - 용량(Capacity):
      - 총 사용가능 전류x 시간
      - 1500 mAh → 1.5A로 1시간 공급가능
    - C 레이트(C-rating) :
      - 연속으로 공급할 수 있는 전류를 의미
      - Continuous current = Capacity x C-rate
      - Ex) 1500 [mAh](capacity) x 30C= 45A continuously



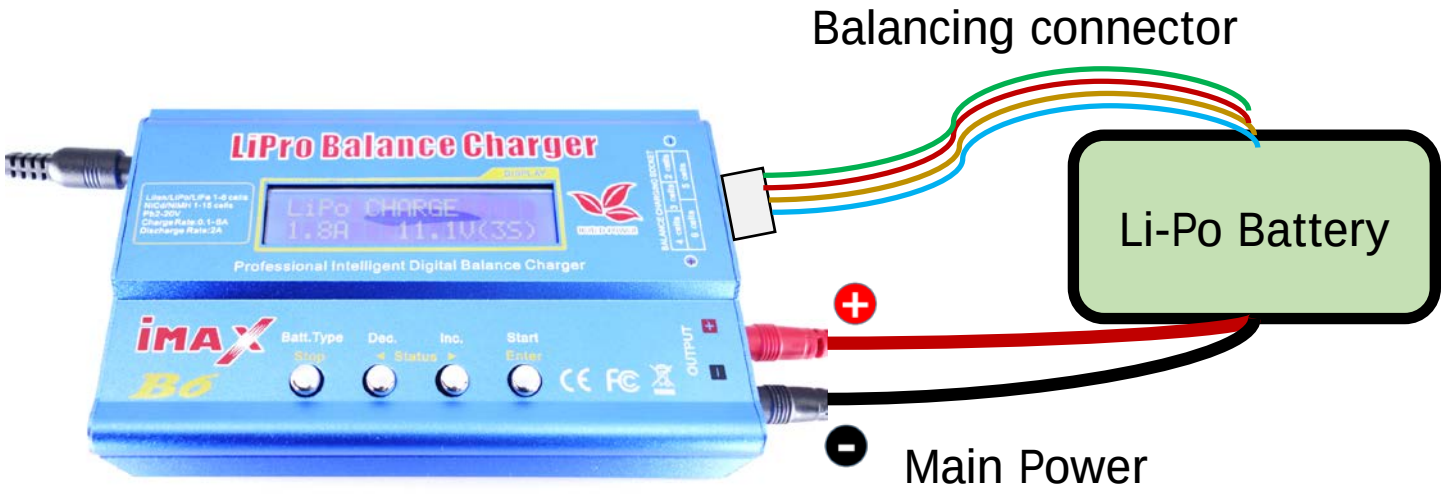
Balancing connector

드론의 구성: Quadcopter

Dept. of Mechanical System Design, Seoul National University of Science and Technology.



- Battery Charger
  - 전자식으로 다양한 타입과 셀 수에 대응
  - 1S~6S 까지 충전 가능
  - balancing connector를 꼭 사용해야 한다.

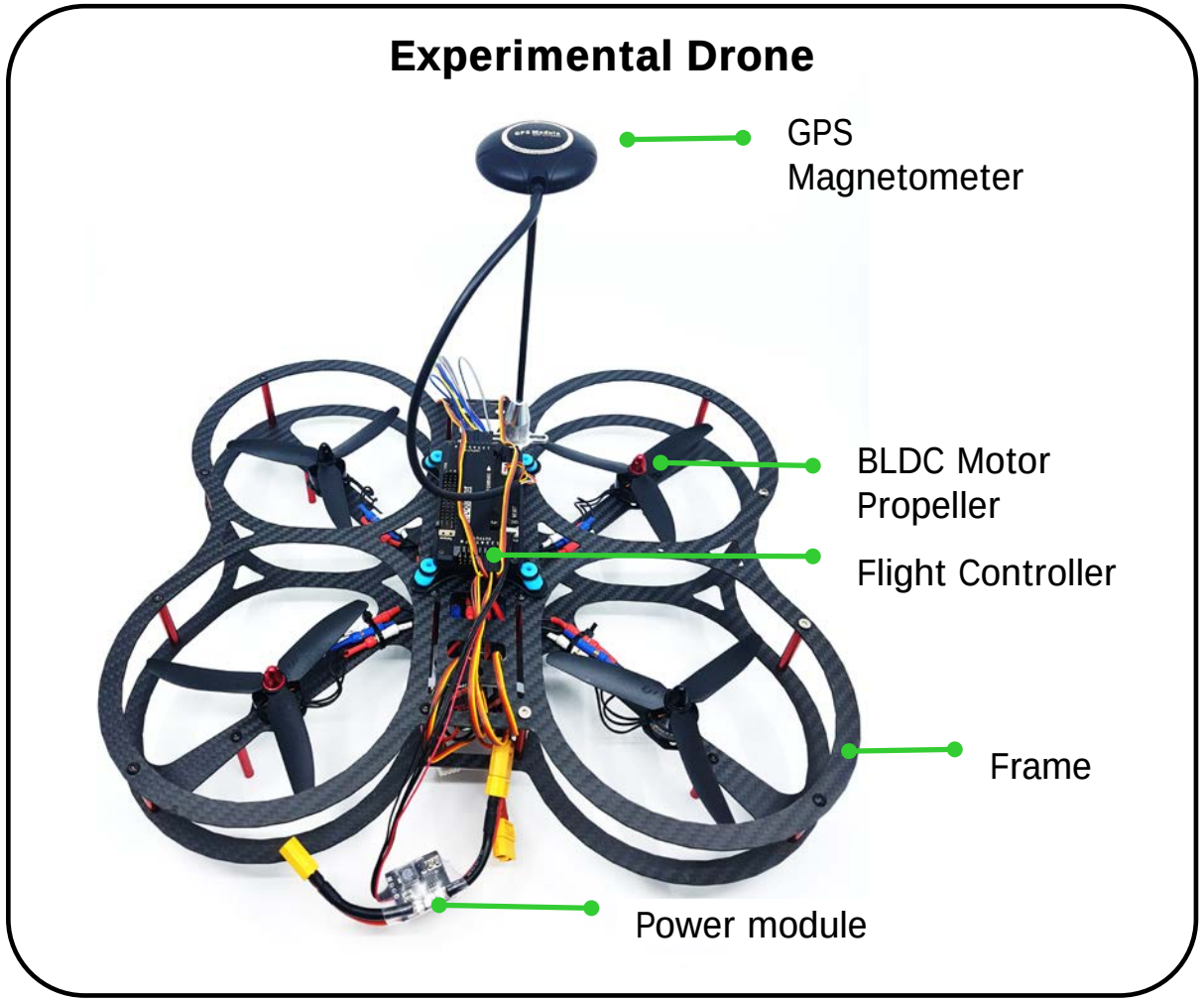


실습용 드론

Prof. HJ Park

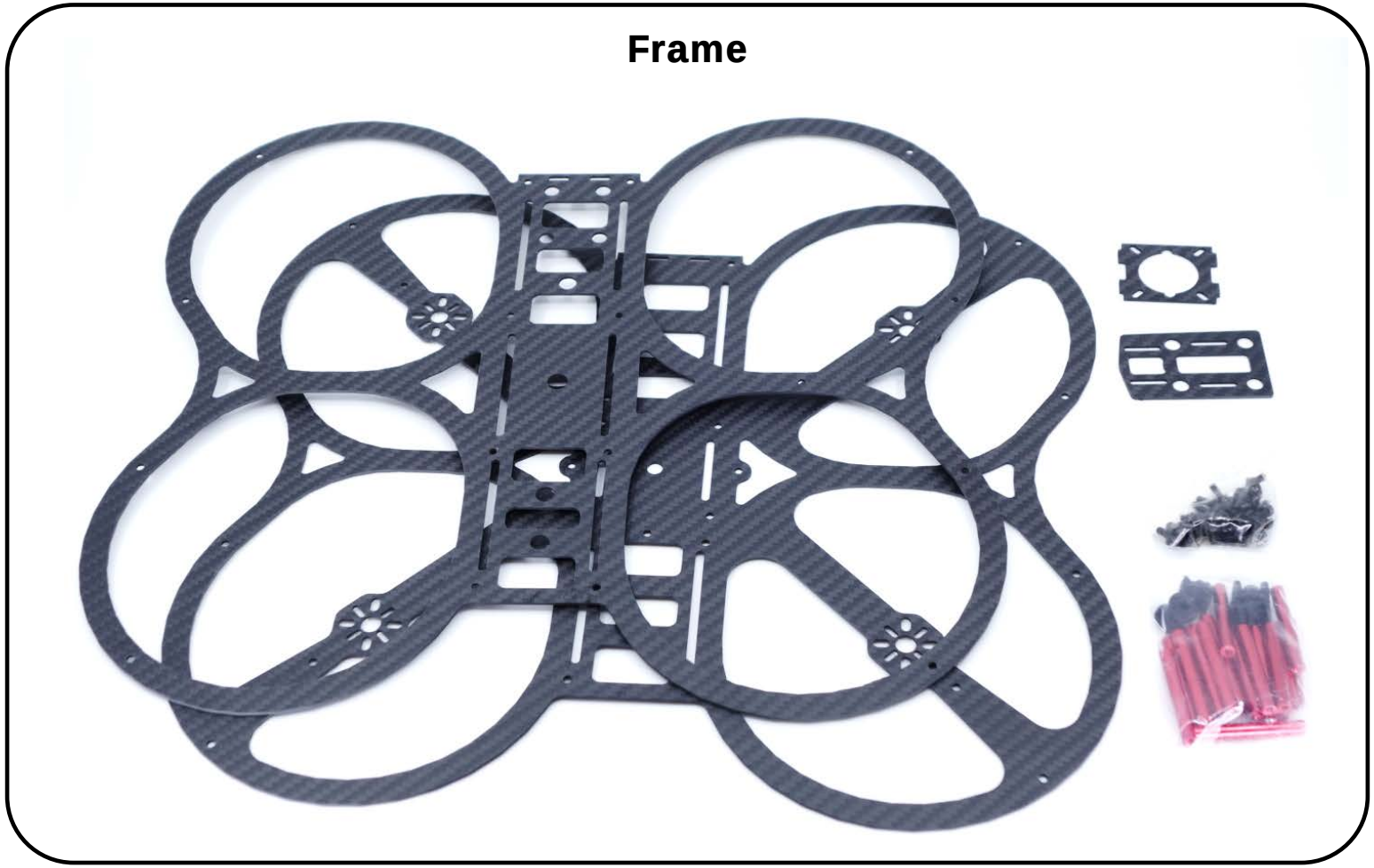
실습용 드론: 전체

- 주요 명칭



실습용 드론: Frame

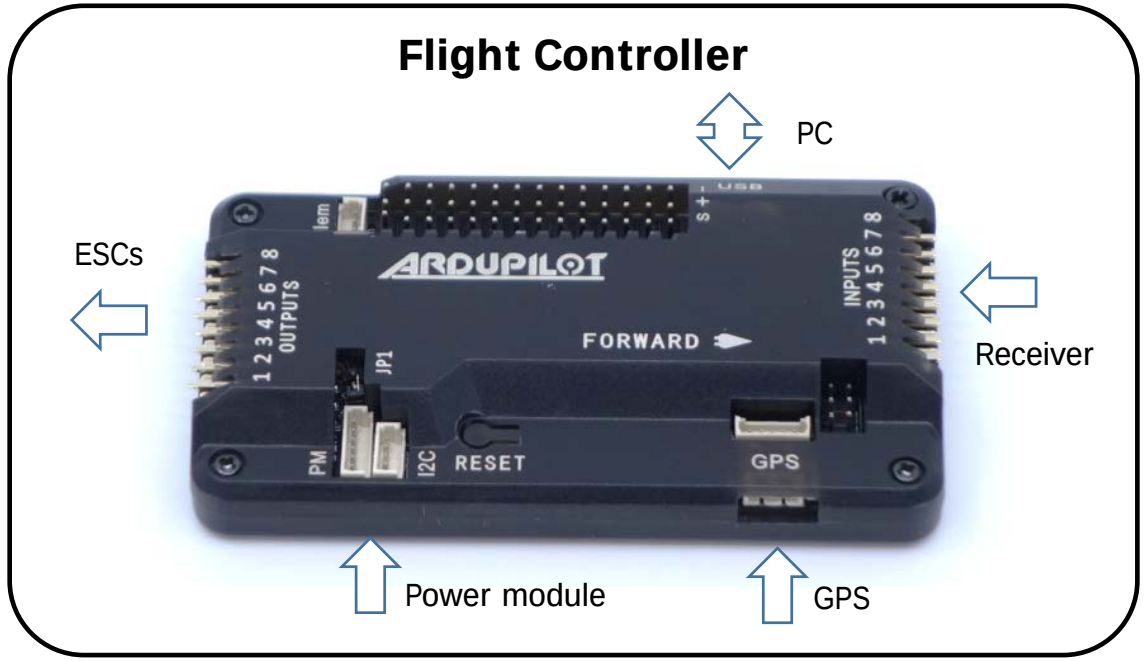
- 프레임
  - Carbone fiber Plate
  - Span 250mm



실습용 드론: FC

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- Flight Controller: Ardupilot 2.8
  - ATmega 2560기반
  - Arduino Mega2560 호환
  - USB programmable

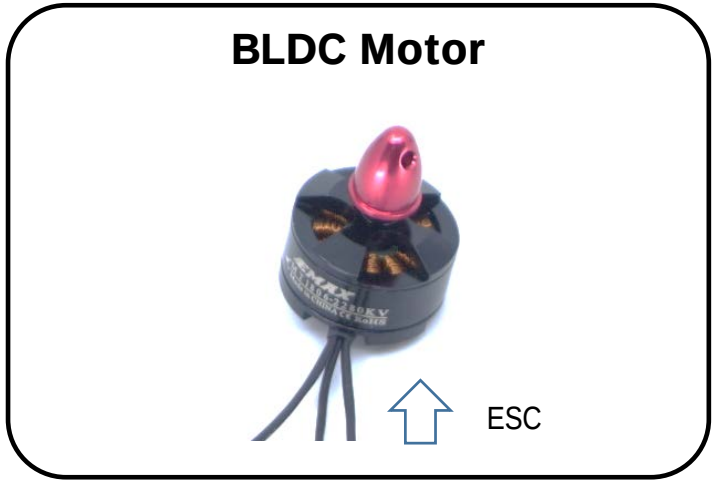


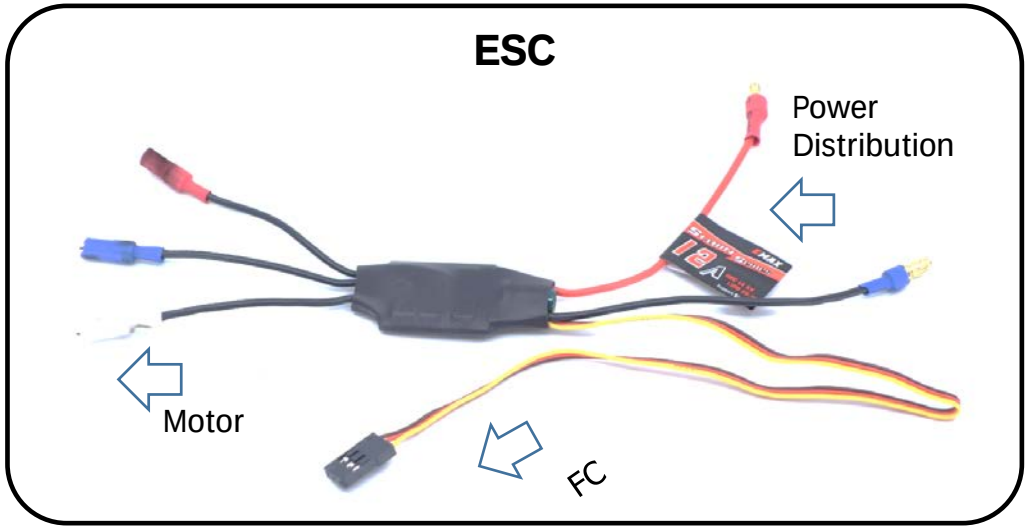
실습용 드론: 모터 ESC

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 모터
  - EMAX - MT1806
  - 속도상수: 2280 KV
    - 2280 KV x 11.1V =25,308 rpm

- ESC
  - EMAX -12A
  - Voltage: 2S~4S





실습용 드론: GPS module

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

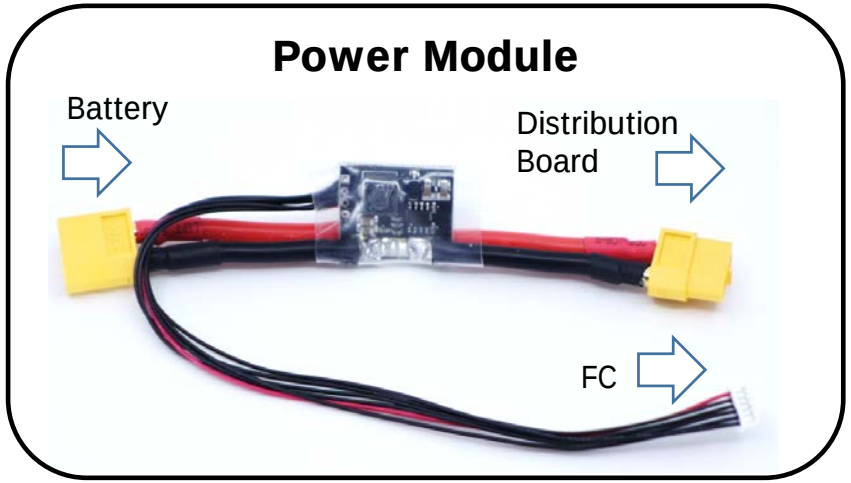
- Ublox 7M + Magnetometer 내장

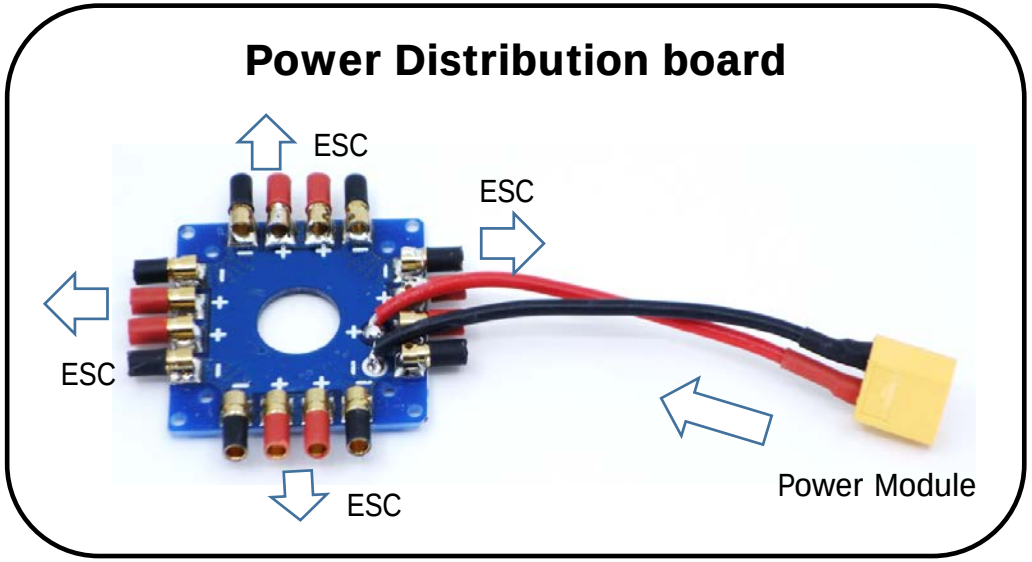
실습용 드론: 전원 모듈/ 전원분배보드

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 전원 모듈
  - 11.1V 배터리 전원을 5V로 변환 FC에 공급
  - Battery 전압, 전류, 정보도 제공

- 전원 분배 보드
  - Power Module로부터의 전원을 각 모터의 ESC에 분배



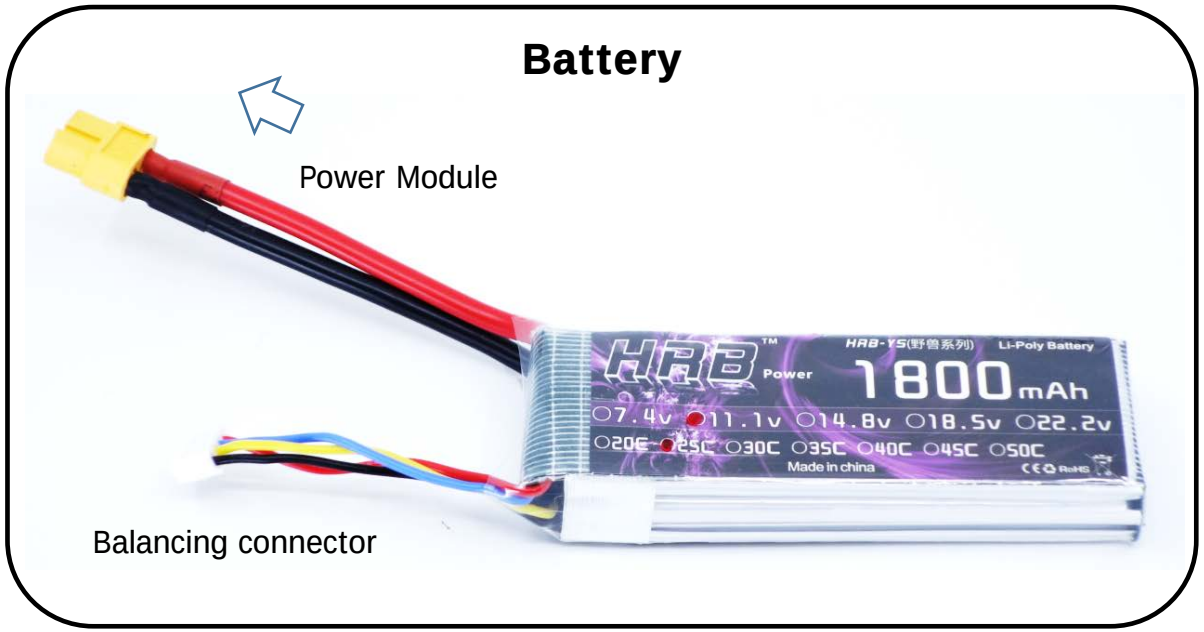


실습용 드론: Battery

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

주요 사양

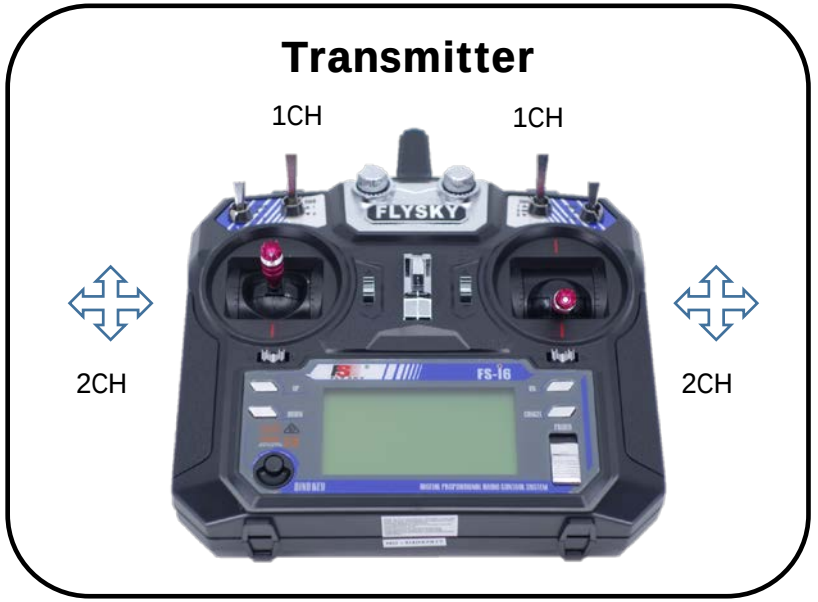
- Voltage
  - 3cell (3S) ➔ 11.1Volts
- Capacity
  - 1800mAh
- Continuous current
  - 25C
  - 1.8 x 25 = 45 A

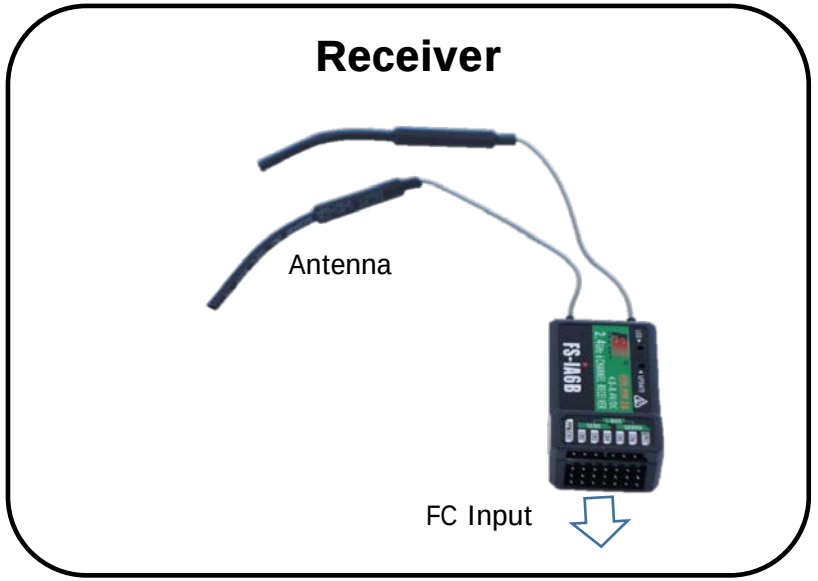


실습용 드론: RC 송수신기

Dept. of Mechanical System Design, Seoul National University of Science and Technology.

- 주요 사양
  - 6 CH
  - RF 범위 : 2.40-2.48GHz
  - RF 전력 : 20dBm 미만





THANK YOU

An Unmanned aerial vehicle (UAV) is a Unmanned Aerial Vehicle. UAVs include both autonomous (means they can do it alone) drones and remotely piloted vehicles (RPVs).