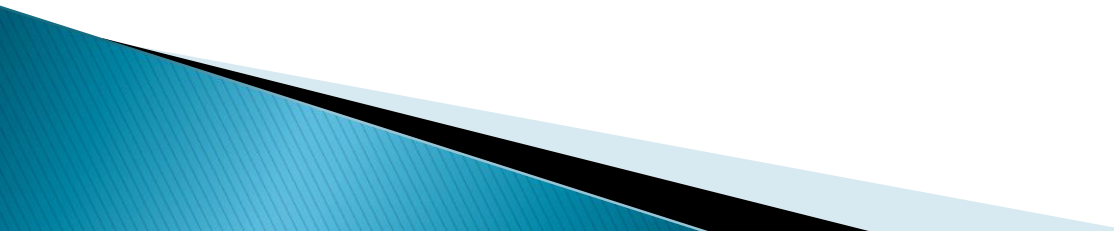




CanberraUAV Workshop Ground Control Stations

Feb 2017

Ground Control Stations

- ▶ Also known as GCS
 - ▶ Communicate with the UAV
 - ▶ Receive telemetry data
 - ▶ Send commands to UAV
- 

GCS –Introduction

- ▶ Telemetry Data
 - Data sent from UAV to GCS
 - Contains information about the current state of the UAV
 - Speed
 - Position
 - Altitude
 - System errors

GCS –Introduction

- ▶ Command data
 - Data sent from GCS to UAV
 - Can be
 - Flight commands (RTL, Goto waypoint)
 - Get/set flight parameters
 - Get/set mission waypoints

GCS – Introduction

- ▶ A GCS Consists of
 - Communications Link
 - GCS Computer
 - GCS Software
 - Other accessories – live video feed, tracking antenna, DGPS base station, etc as required

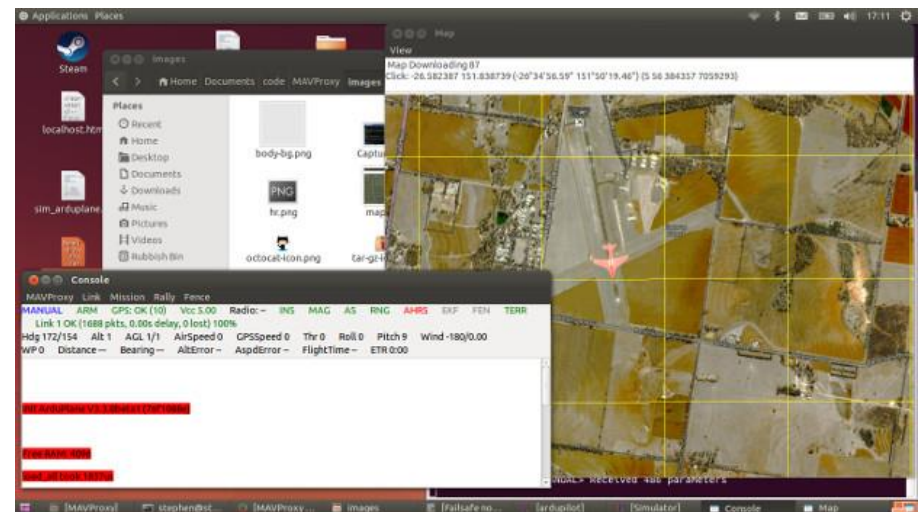


GCS – Software Options

- ▶ Most GCS software is run on laptops
- ▶ Different options depending on
 - Which flight controller is used
 - GCS Operating System
 - Require features
- ▶ Open source and commercial offerings

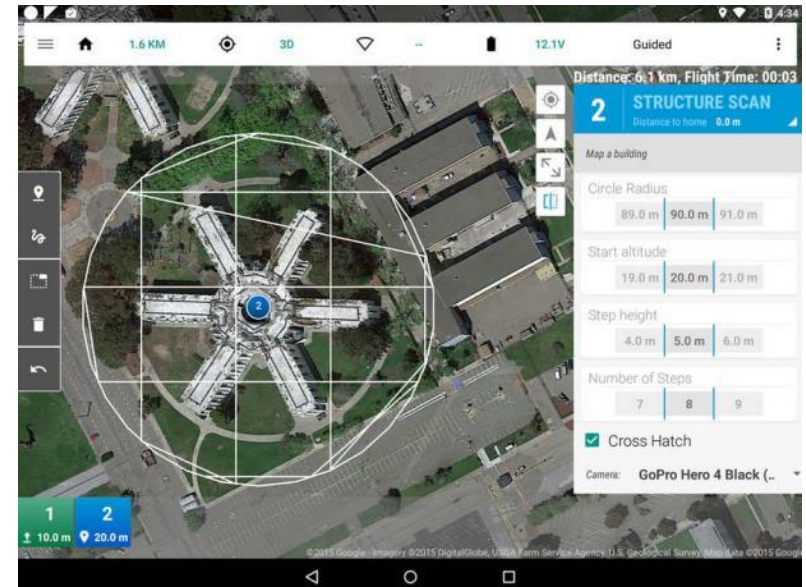
GCS – Software Options

Software	Runs on Linux	Runs on Windows	Runs on OSX
Mission Planner		YY	Y
MAVProxy	YY	Y	
APM Planner 2	YY	YY	YY
Qground control	Y	Y	YY
UgCS	YY	YY	YY



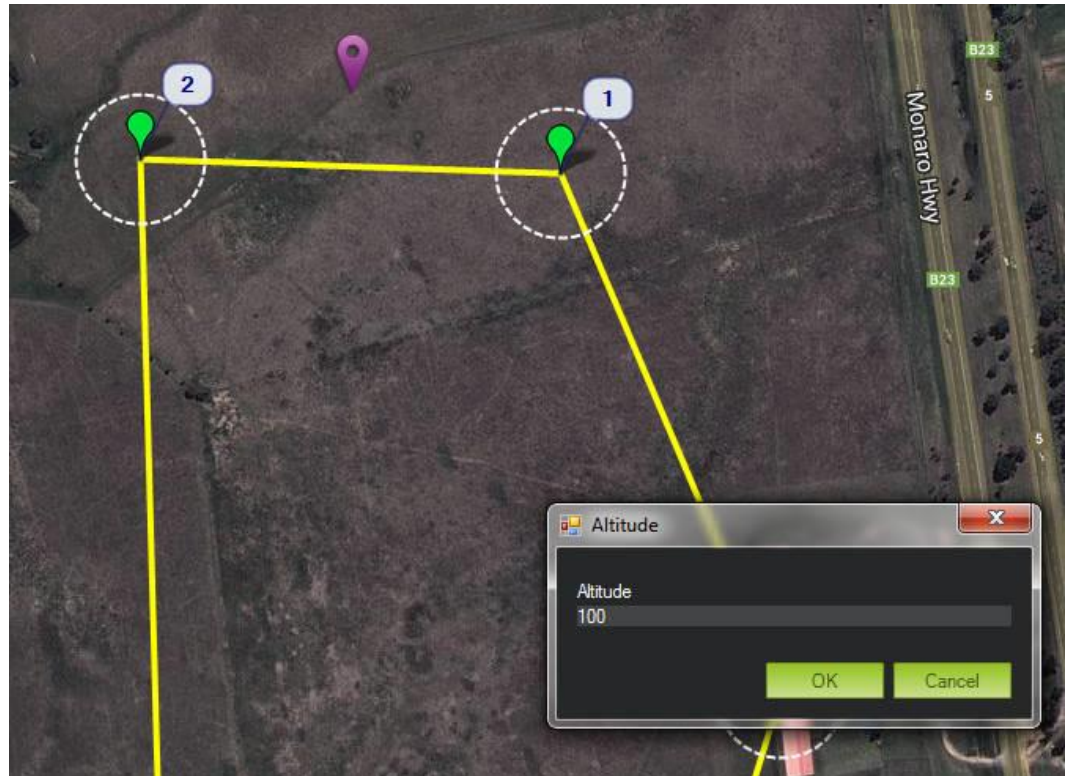
GCS – Software Options

Software	Runs on Android	Runs on iOS
Tower	YY	
MAVPilot		YY
SidePilot		YY
AndroPilot	YY	



GCS – Software Options

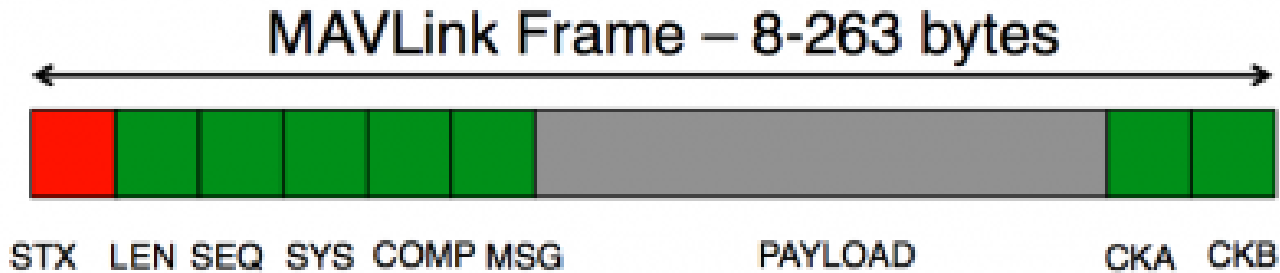
- ▶ Compatibility and features vary widely between GCS programs



GCS – MAVLink

- ▶ Micro Air Vehicle Link
- ▶ Standardised protocol for most open-source flight controllers
 - Though some flight controllers may have extra MAVLink messages
- ▶ Efficient and low datarate
- ▶ Includes CRC to ensure validity of data
- ▶ 3 versions – 0.9, 1.0, 2.0
- ▶ Arduplane can use 1.0 or 2.0 (default 1.0)

GCS – MAVLink



Byte Index	Content	Value	Explanation
0	Packet start sign	v1.0: 0xFE (v0.9: 0x55)	Indicates the start of a new packet.
1	Payload length	0 – 255	Indicates length of the following payload.
2	Packet sequence	0 – 255	Each component counts up his send sequence. Allows to detect packet loss
3	System ID	1 – 255	ID of the SENDING system.
4	Component ID	0 – 255	ID of the SENDING component.
5	Message ID	0 – 255	ID of the message – the id defines what the payload “means” and how it should be correctly decoded.
6 to (n+6)	Data	(0 – 255) bytes	Data of the message, depends on the message id.
(n+7) to (n+8)	Checksum (low byte, high byte)	ITU X.25/SAE AS-4 hash, excluding packet start sign, so bytes 1..(n+6)	

GCS – MAVLink

GPS_RAW_INT ([#24](#))

The global position, as returned by the Global Positioning System (GPS). This is NOT the global position estimate of the system, but rather a RA estimate. Coordinate frame is right-handed, Z-axis up (GPS frame).

Field Name	Type	
time_usec	uint64_t	Timestamp (microseconds since UNIX epoch or microseconds since boot)
fix_type	uint8_t	See the GPS_FIX_TYPE enum.
lat	int32_t	Latitude (WGS84), in degrees * 1E7
lon	int32_t	Longitude (WGS84), in degrees * 1E7
alt	int32_t	Altitude (AMSL, NOT WGS84), in meters * 1000 (positive for above sea level, negative for below sea level)
eph	uint16_t	GPS HDOP horizontal dilution of position (unitless). If unknown, set to 255
epv	uint16_t	GPS VDOP vertical dilution of position (unitless). If unknown, set to 255
vel	uint16_t	GPS ground speed (m/s * 100). If unknown, set to 255
cog	uint16_t	Course over ground (NOT heading, but direction of movement) in degrees. If unknown, set to 255
satellites_visible	uint8_t	Number of satellites visible. If unknown, set to 255

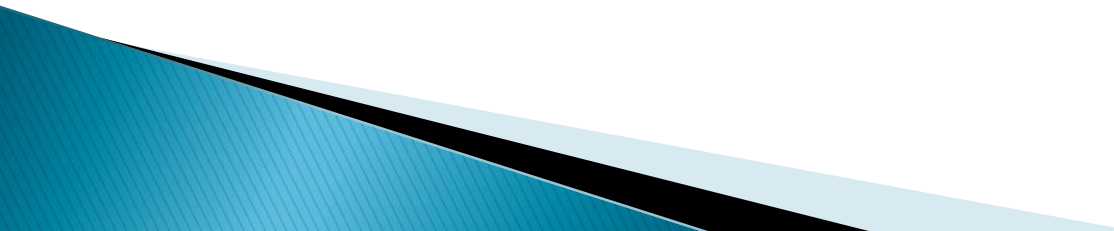
GCS – MAVLink

MAV_CMD

Commands to be executed by the MAV. They can be executed on user request, or as part of a mission script. If the action is used in a mission script, Param 1, Param 2, Param 3, Param 4, X: Param 5, Y:Param 6, Z:Param 7. This command list is similar what ARINC 424 is for commercial aircraft.

CMD ID	Field Name	
16	MAV_CMD_NAV_WAYPOINT	Navigate to MISSION.
	Mission Param #1	Hold time in decimal seconds. (ignored by fixed wing)
	Mission Param #2	Acceptance radius in meters (if the sphere with this radius intersects the ground projection of the orbit at any point)
	Mission Param #3	0 to pass through the WP, if > 0 radius in meters to pass above/below orbit. Allows trajectory control.
	Mission Param #4	Desired yaw angle at MISSION (rotary wing)
	Mission Param #5	Latitude
	Mission Param #6	Longitude
	Mission Param #7	Altitude
17	MAV_CMD_NAV_LOITER_UNLIM	Loiter around this MISSION an unlimited amount of time
	Mission Param #1	Empty
	Mission Param #2	Empty
	Mission Param #3	Radius around MISSION, in meters. If positive loiter clockwise, if negative counter-clockwise.
	Mission Param #4	Desired yaw angle.
	Mission Param #5	Latitude
	Mission Param #6	Longitude
	Mission Param #7	Altitude

GCS – MAVLink

- ▶ There are MAVLink messages for sending/receiving parameters and missions
 - ▶ Typically, a flight controller may only send some of the messages – depending on it's features, settings and current state
- 

GCS – MAVLink

- ▶ MAVLink does include any encryption
 - Up to the user to implement in their communications link
- ▶ MAVLink 2.0 includes a “signing key”
 - 32-bit number
 - Flight controller will only accept commands from packet signed with this key
 - Disabled by default

GCS – Flight Planning

- ▶ Creating the waypoints to achieve the mission objectives

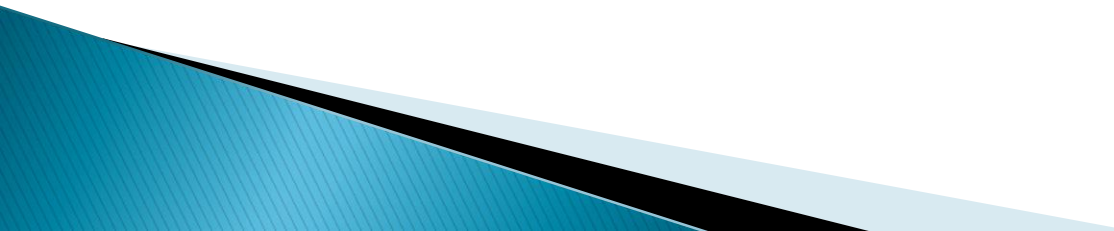
The screenshot displays a flight planning software interface. At the top, there is a navigation bar with tabs: FLIGHT DATA, FLIGHT PLAN, INITIAL SETUP, CONFIG/TUNING, SIMULATION, TERMINAL, HELP, and DONATE. Below the navigation bar, a map shows a mission plan with 5 waypoints (1-5) and a 'Home' location. The waypoints are connected by yellow lines, forming a path that starts at Home, goes to 1, 2, 3, 4, 5, and returns to Home. The map also shows a distance of 0.7989 km, a previous altitude of 522.46 m, and an azimuth of 67 degrees. On the right side, there is a 'Zoom' slider and an 'Action' panel with buttons for 'Load WP File', 'Save WP File', 'Read WPs', and 'Write WPs'. Below the map, there is a 'Waypoints' table with columns for Command, Lat, Long, Alt, Delete, Up, Down, Grad %, Dist, and AZ.

WP	Command	Loiter Radius	Loiter Radius	Default Alt	Absolute Alt	Verify Height	Lat	Long	Alt	Delete	Up	Down	Grad %	Dist	AZ
1	WAYPOINT	0	0	0	0		-35.0407928	117.8277898	100	X	⬆	⬆	95.7	104.5	1
2	WAYPOINT	0	0	0	0		-35.0406786	117.8260410	100	X	⬆	⬆	0.0	159.7	275
3	WAYPOINT	0	0	0	0		-35.0417239	117.8251612	100	X	⬆	⬆	0.0	141.2	215
4	WAYPOINT	0	0	0	0		-35.0428395	117.8259873	100	X	⬆	⬆	0.0	145.1	149
5	WAYPOINT	0	0	0	0		-35.0427165	117.8274572	100	X	⬆	⬆	0.0	134.5	84

GCS – Flight Planning

- ▶ What is the mission objective?
 - Primary and secondary goals
 - Payload required
 - UAV required
- ▶ Most GCS software packages have a mission planning screen where you can drag-n-drop waypoints

GCS – Flight Planning

- ▶ Considerations
 - Takeoff/landing area
 - Hills/Terrain
 - Flight altitude
 - Mission length (km)
 - Weather (wind)
 - Communications coverage
- 

GCS – Flight Planning

- ▶ If possible, run the mission in SITL beforehand, to ensure the waypoints are correctly laid out
- ▶ Some GCS software packages have auto-generation of waypoints for mowing-the-lawn surveys



Practical Session 1 (20min)

- ▶ Create a mission that:
 - Perform an aerial survey of the Snowy Hydro base
- ▶ Considerations:
 - Takeoff/landing at CMAC
 - Landing will be manual
- ▶ Create the mission, run in SITL
 - `cd ./ArduPlane`
 - `../Tools/autotest/sim_vehicle.py`
- ▶ Two options for GCS tool to use for mission planning (choose one)
 - Connect Mission Planner via UDP, port 14550
 - Use `module load misseditor` in MAVProxy

GCS – Advanced Planning

- ▶ Geofences
 - A single closed polygon
- ▶ UAV will turn back if it crosses outside of the polygon
 - Note that the UAV's inertia may send it beyond the fence for a short period



GCS – Advanced Planning

- ▶ Rally points
 - Instead of a single Home point, have a set of rally points
 - On RTL, the UAV will head to the nearest rally point



GCS – Advanced Planning

▶ Terrain Following

- Terrain data stored on Pixhawk's SD card
- Arduplane will look at this database to estimate it's AGL
- Available in AUTO, RTL and other flight modes. Will maintain a constant height above ground
- **Set `TERRAIN_ENABLE` to 1 and `TERRAIN_FOLLOW` to 1**
- Note the datasource is the SRTM data, so is only accurate to 20m

GCS – Post flight analysis

- ▶ Two types of logfiles
 - GCS – saved copy of MAVlink stream (tlog)
 - APM – saved on SD card (bin)
- ▶ Bin log has more messages at a faster rate
 - Generally the preferred log when analysing a flight
- ▶ Tlog is on the GCS, so can be used if the UAV goes missing or is destroyed
 - Still worth searching the crash site for the SD card!

GCS – Post flight analysis

- ▶ Tlogs are stored in:
 - Mission Planner
 - C:\Program Files (x86)\Mission Planner\logs
 - MAVProxy
 - Same folder that MAVproxy was run from (unless using the --aircraft option)

GCS – Post flight analysis

- ▶ Most flight analysis tools will work with both bin files and tlog files
- ▶ Popular Flight Analysis tools:
 - Mission Planner
 - MAVExplorer (part of MAVProxy)

GCS – Post flight analysis

Mission Planner 1.3.43 build 1.1.6202.10835

FLIGHT DATA | FLIGHT PLAN | INITIAL SETUP | CONFIG/TUNING | SIMULATION | TERMINAL | HELP | DONATE

UDP | 115200 | CONNECT

300 NW 330 345 0 15 30 NE 60

10 5 0 5 10

DISARMED

00:00:00

10 5 0 5 10

AS 0.0 Unknown
GS 0.0 0>0

EKF Vibe **GPS: No GPS**

Quick | Actions | Pre-flight | Gauges | Status | Servo | Telemetry Logs | D | A | ▶

Load Log

Play 0.00 %

Tlog > Kml or Graph

Speed x 1.0

1/10 1/4 1/2 1x 2x 5x 10x

Canberra Model Aircraft Club Flying Field

Grassiano Nature Reserve

B23

B23

hdop: 0.0
Sats: 0
162077.64

GEO

MAVExplorer

MAVExplorer

GCS – Post flight analysis

▶ Mechanical Failures

- These appear in the log as a sudden divergence in the desired roll and pitch vs the vehicles actual roll and pitch



GCS – Post flight analysis

▶ Excessive Vibration



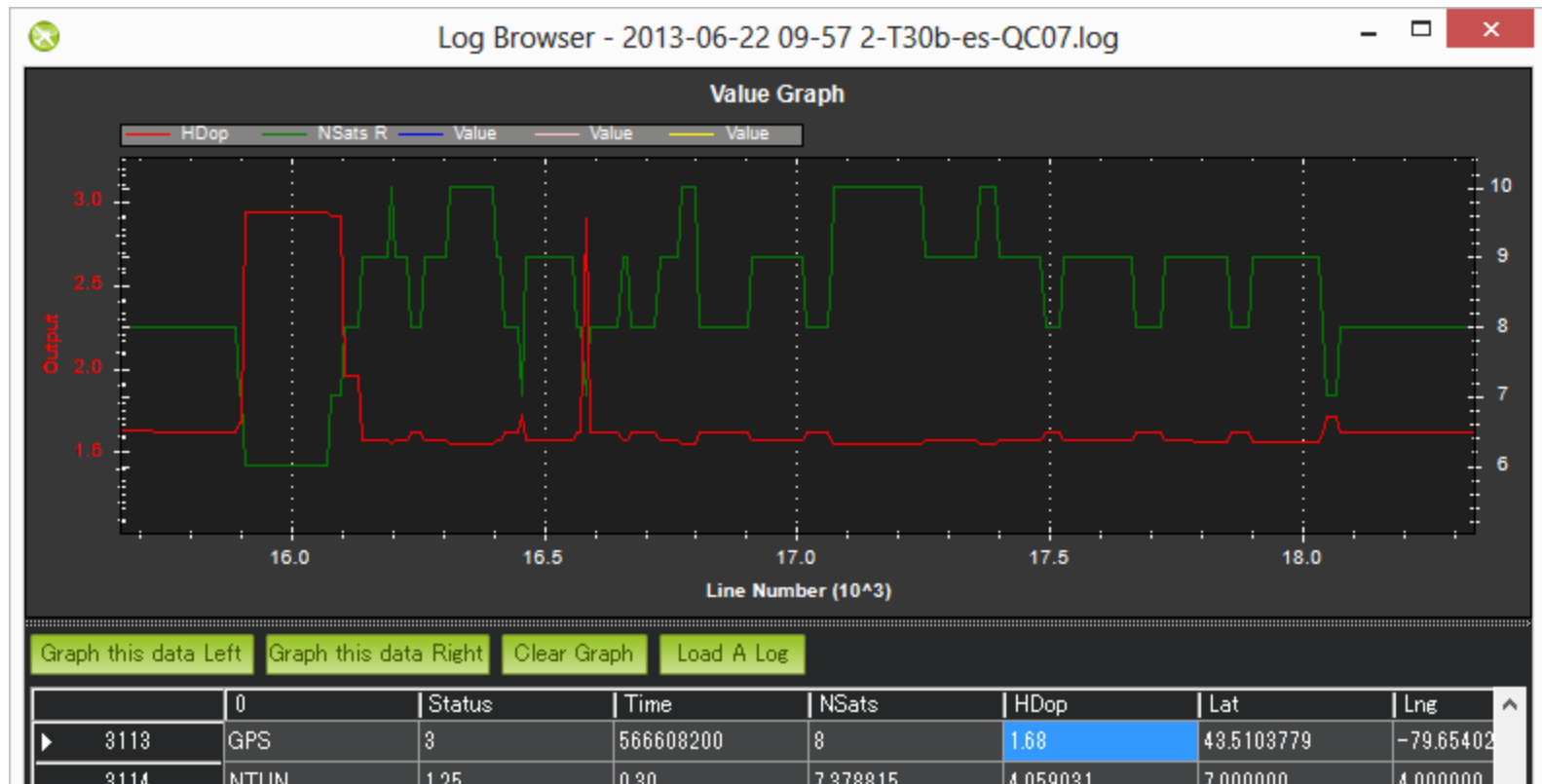
GCS – Post flight analysis

- ▶ Compass Interference
 - Look for patterns between `mag_field` and `throttle`



GCS – Post flight analysis

▶ GPS Glitches



GCS – Post flight analysis

- ▶ Power brown-outs, if APM voltage varies by more than 0.15V, or goes below 4.7V



Practical Session 2 (20min)

▶ Logfile Analysis

- Find a logfile generated by SITL(./ArduPlane/logs) for the bin file
- For more interesting data:
<http://discuss.ardupilot.org/t/altitude-hold-and-stability/14536>

▶ Two options for Analysis tool (choose one)

- Mission Planner
- MAVExplorer

▶ Check GPS

- `GPS.Nsats` and `GPS.HDop` messages

▶ Check Vibration

- `IMU.AccX`, `IMU.AccY`, `IMU.AccZ` messages

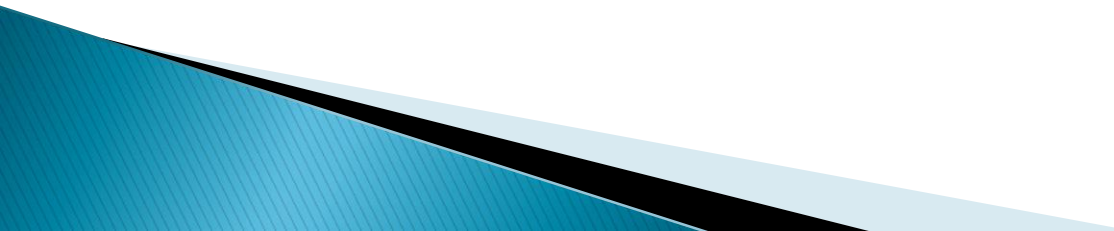
GCS – Inflight Monitoring

- ▶ APM outputs a lot of telemetry data
- ▶ How to watch all this in realtime?

The screenshot displays a GCS interface with several windows:

- Terminal (top left):** Shows MAVProxy telemetry data including mission status, flight time, and waypoint information. Key data points include: "Link 1 OK 100.0% (33832 pkts, 0 lost, 0.00s delay)", "WP 19/63 Distance 0.00m Bearing 157 ARError 2L AltError 0.0L FlightTime 10:16 ETR 2:14", and "APM: Passed waypoint #18 dist 159m".
- Graph (middle left):** A line graph titled "VFR HUD airspeed" and "VFR HUD groundspeed" showing speed over time.
- Camera Image (top right):** A window titled "View Camera Image" showing a dark, low-light aerial view.
- Map (bottom right):** A map window showing a top-down view of the flight path with a blue circle indicating the current position. A tooltip displays coordinates: "Click: -27.357900 151.239629 (-27°21'28.44" 151°14'22.66") (S 56 325884 6972693) Distance: 56.8m 0.00m Bearing 256.9".
- Terminal (bottom):** Shows a series of commands and responses: "Porter: AUTO> param set SIM_SPEEDUP 0.1", "Porter: AUTO> param set SIM_SPEEDUP 0.2", "Porter: AUTO> param set SIM_SPEEDUP 1", "Porter: AUTO> Selected region 8 ridx=8", "Selected region 8 ridx=8", "Selected region 10 ridx=10", "Selected region 10 ridx=10", "Selected region 8 ridx=8", "Selected region 8 ridx=8", "Selected region 8 ridx=8", "Selected region 8 ridx=8", "Selected region 8 ridx=8", "Selected region 12 ridx=12".

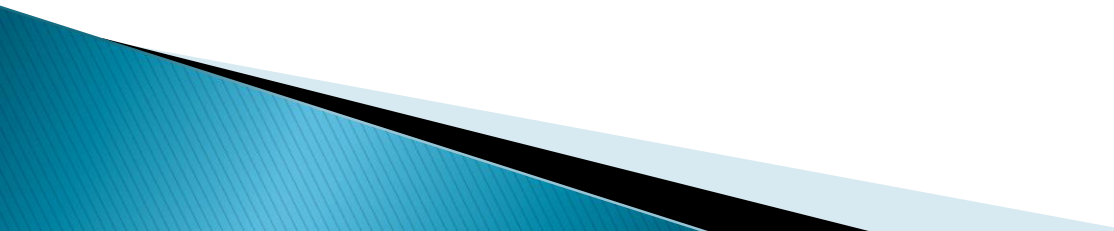
GCS – Inflight Monitoring

- ▶ Decide which data is important
 - ▶ May vary depending on mission phase
 - Speed, Altitude during takeoff and landing
 - Moving map during mission
- 

GCS – Inflight Monitoring

- ▶ Things to typically monitor
 - Speed
 - Altitude
 - UAV Position (longitude/latitude) along with waypoints
 - Battery voltage
 - Telemetry link quality
 - Any error messages
- ▶ Anything that, if not detected in a short time, could result in a crash

GCS – Inflight Monitoring

- ▶ Have backup plans for common failure scenarios
 - ▶ Practice!
 - In SITL
 - In test flights
 - ▶ Consider having multiple GCS stations to split the workload
- 

The End!

- ▶ Flight Planning
 - ▶ Logfile analysis
 - ▶ Inflight monitoring
- 