DEFENCE AND SPACE

RF Sensing from Unmanned Airborne Systems

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Drone as a payload test platform

Use of a conventional trials aircraft is expensive:

- Typical £1,250 to £2,500 per flight hour
- Additional costs for first required for certification and installation (£30,000+).

Meaning that trials are prohibitive for studies and experiments without a substantial funding source.

Commercial drones, typically used for cinematography, offer a reasonable payload mass capability for a relatively low cost – after initial outlay only cost for operation is labour.

These drones have a maximum flight time of ~15min (with payload) between battery charges, sufficient for a few imaging sequences. For more imaging sequences the battery could be recharged between runs (4hrs from empty) or replaced with spares for immediate turn-around.

Drone as a payload test platform

Control:

- Drone equipped with a flight controller including GPS and INU
  - Automatic flight mode allows automatic take-off and landing, and flight upon a set of pre-defined waypoints (lat,long,alt).
  - Manual flight mode allows joystick control

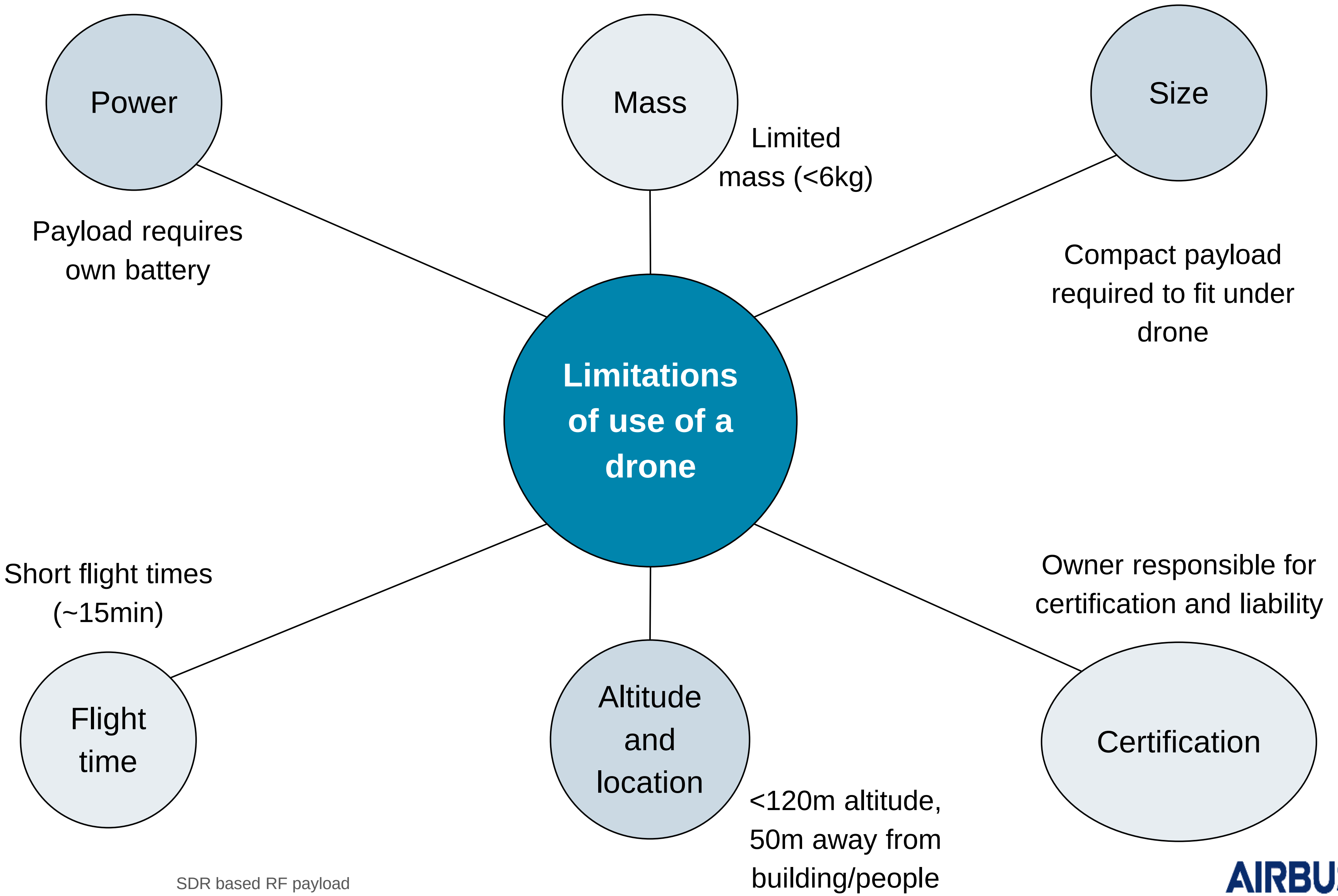
Certification:

- Does not required ATC approval:
  - Has to remain within eye sight at all times and not cross into controlled airspace
  - Remain 50m away from buildings/people and below altitude of 120m
- CAA certified drone pilot enables us to offer the use of the drone for commercial use

Specification	Value
Size	Deployed: 1668mm x 1518mm x 759mm Stowed: 640mm x 582mm x 623mm
Max payload mass	6kg
Hovering accuracy	Vertical: 0.5m Horizontal: 1.5m
Max altitude	2500m (limited to 120m without CAA permission)
Max speed	Horizontal: 18m/s Ascent: 5m/s Descent: 3m/s
Hovering time	No payload: 35min 6kg payload: 18min
Battery recharge time	<4hrs

DJI M600 Drone capability

Drone as a payload test platform



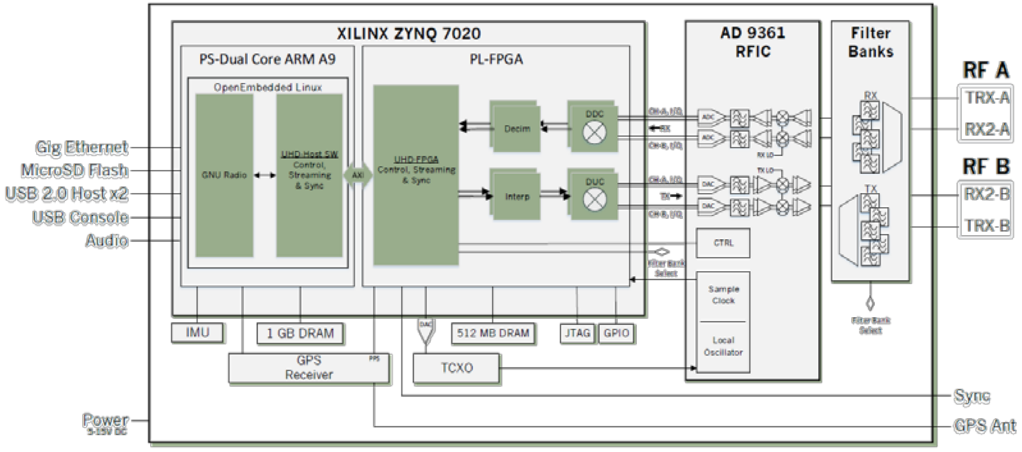
RF sensing from UAV

Synthetic Aperture Radar (SAR) payload based around a COTS Software Defined Radio (SDR):

- SDR are compact RF transceivers, with optional CPU/FPGA control embedded, commonly used for communications -> re-purposed as a radar
  - Many have additional sensors embedded such as GPS, IMU, SD card
- Controlled via software – C++ executables generated to control functionality (VHDL coding of FPGA also possible but much more complex)

SDR performance (AD9361 transceiver):

- <56MHz instantaneous bandwidth
- 70MHz – 6GHz centre frequency (with suitable antenna)
- > 10dBm output power (- peripherals losses)
- 8dB Noise Figure (+ peripherals losses)



Example SDR architecture

RF sensing from UAV

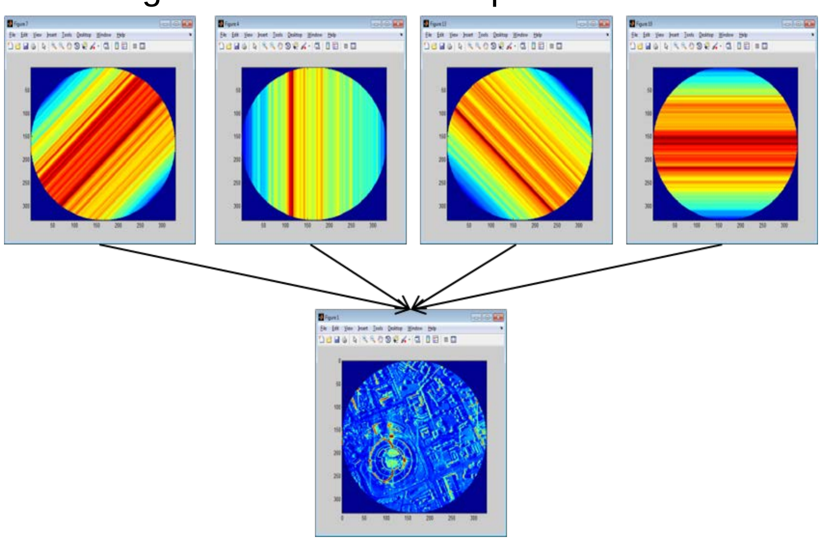
SDR has limited transmit power – limiting range and/or resolution unless external amplifier used

- One potential solution is to make use of radar tomography – no additional amplifier required

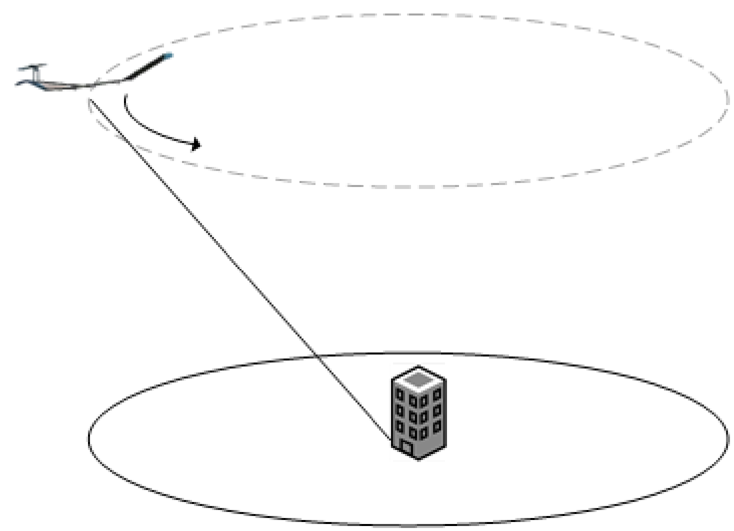
Radar tomography:

- Images from a series of cuts, from a circular trajectory flown around the target, are combined to form a combined image with finer resolution than that of each individual image
- The technique allows coarse range resolution to be used (increasing range and/or SNR), with the final image dependant upon the azimuth resolution of each image

Images taken at different points of circle



Combined to form final image



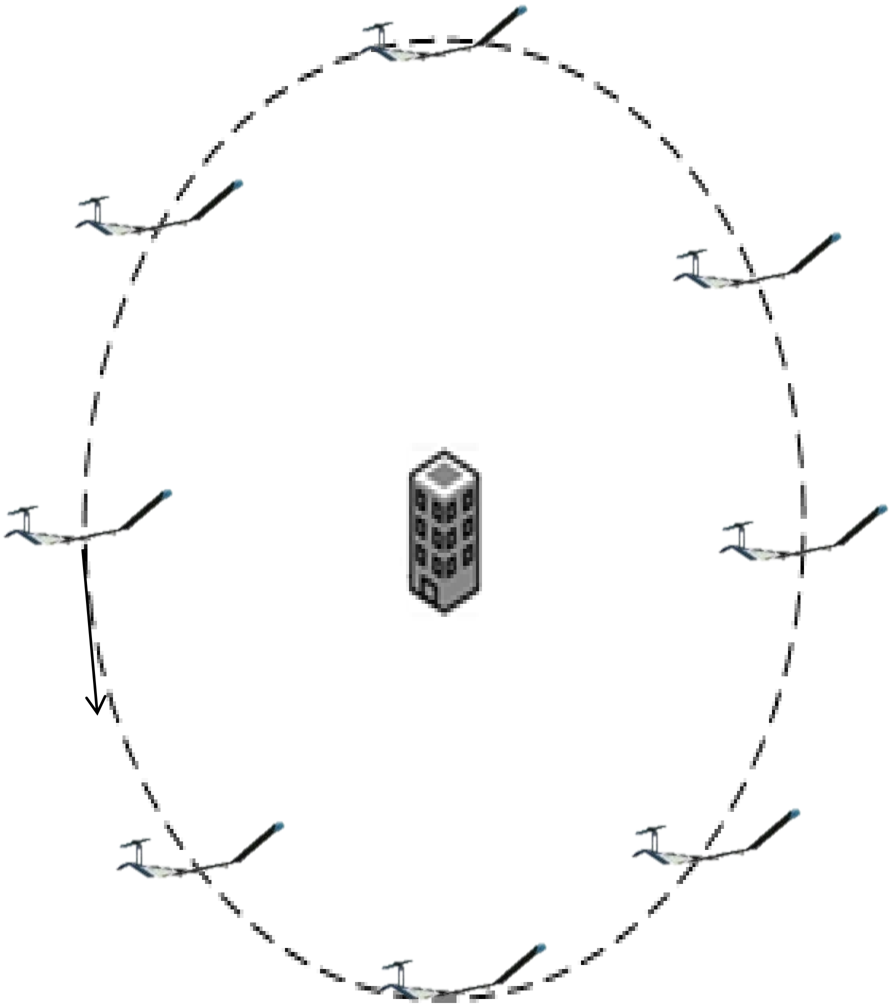
Concept Overview

Radar imagery:

- Payload looks down on scene to form radar image

Radar tomography:

- Payload collects imagery from all around the target
- Each image can be a coarse range resolution image – like a set of line images – a 1-D image
- These images are combined in a tomographic way to enable fine resolution imagery to be generated – whose resolution depends upon the azimuth resolution of each cut

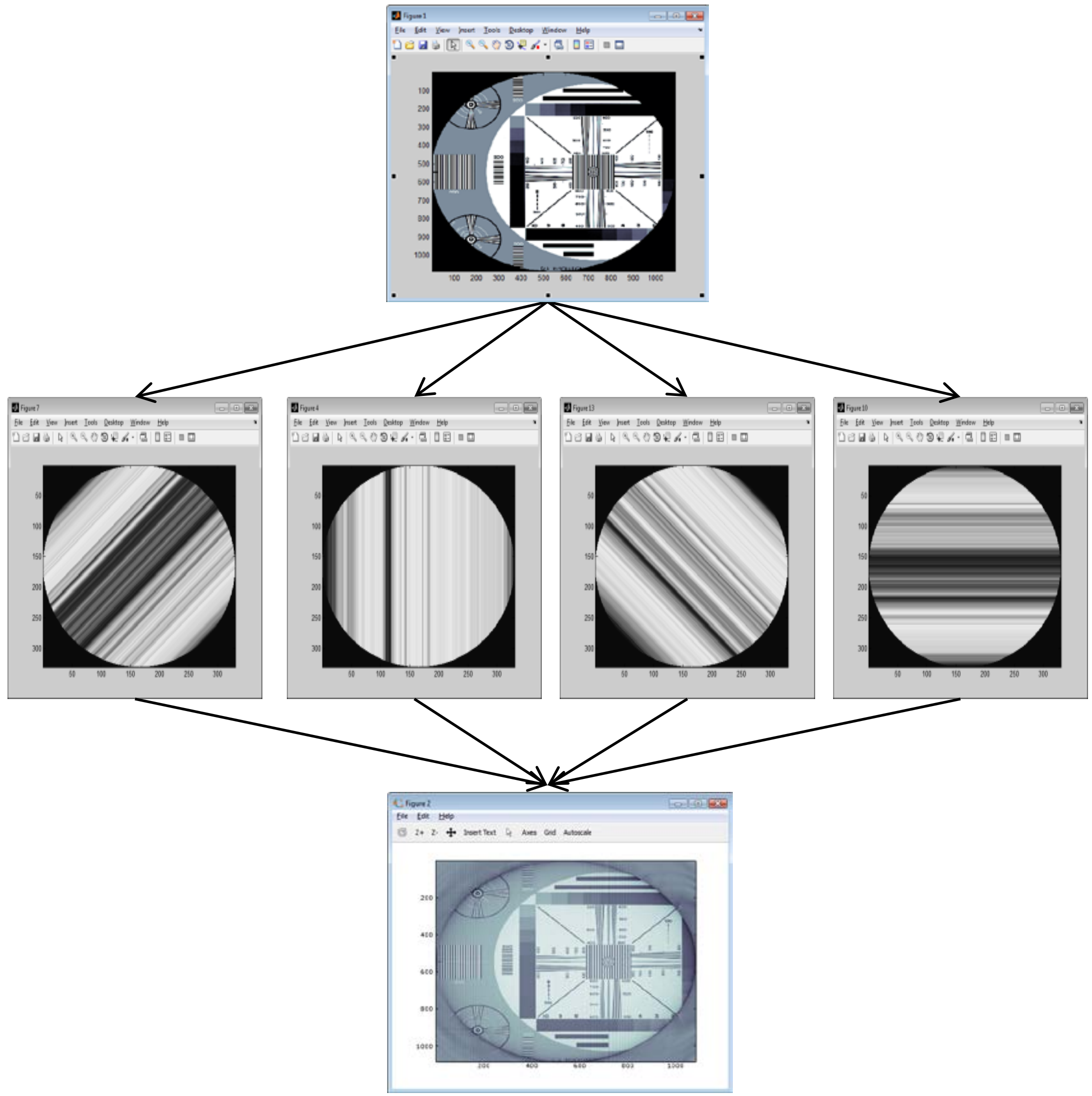


Simulation/modelling

Modelling performed to assess feasibility of technique

- Original image (scene) split into simulated individual images (simulated images being acquired by low range resolution system around the scene)
- Individual (line) images combined using radar tomography technique to provide final image

Conclusion: technique enables a fine resolution images to be generated from low resolution imagery



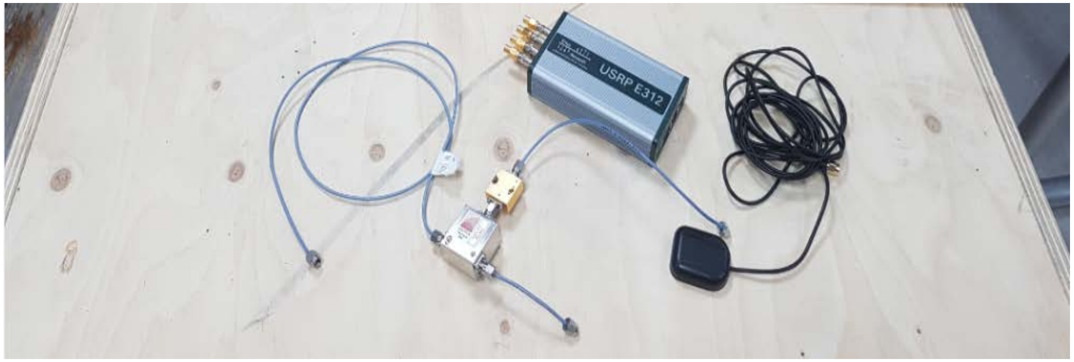
Proof-of-concept Hardware

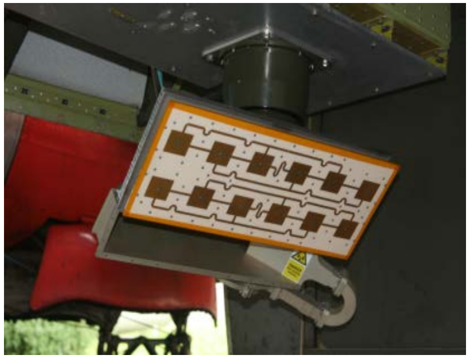
Payload hardware – not SWaP optimised, what was available in laboratory:

- COTS SDR for instrument electronics with internal battery, GPS receiver, IMU, SD card.
- Lightweight airborne RF antenna (S-band),
- Ancillaries – GPS antenna, circulator, limiter, RF cables
- No external amplifier fitted (using 0.01W output from SDR), this limits the operational range to a few km. Suitable amplifier + battery to power identified if wanted to increase range.

SWaP:

- Size: Electronics 133 x 68 x 32mm + 80 x 40 x 20mm, Antenna 470 x 200 x 54mm
- Mass: <1.4kg
- Power: Uses internal battery
- Data: stored on SD card





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Hardware integration

Payload hardware integrated onto drone

- Supported on existing drone mounting rails

Functional system proven:

- Drone can fly planned flight path autonomously (pre-planned flight plan)
- Payload can record data autonomously based on a sequence on start/stop points in flight plan (pre-planned)
- Payload uses waveform readout – waveforms generated on ground and loaded into SDR
- Data stored on SD card, transferred off on-ground
- Data processed on ground into imagery

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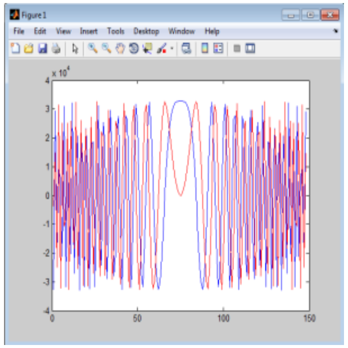
First flight

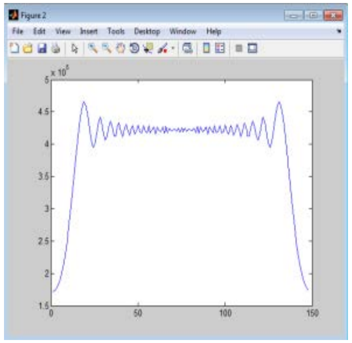
First results

Conventional SAR imagery obtained:

- Use of linear FM chirp
- 3.5m resolution
- 1km slant range



Time domain



Freq domain

System can generate bandwidth required to achieve <1m resolution but would require:

- External amplifier (to maintain SNR)
- Pulse-to-pulse chirp stitching to increase bandwidth over instantaneous bandwidth

Radar tomographic collections and analysis underway

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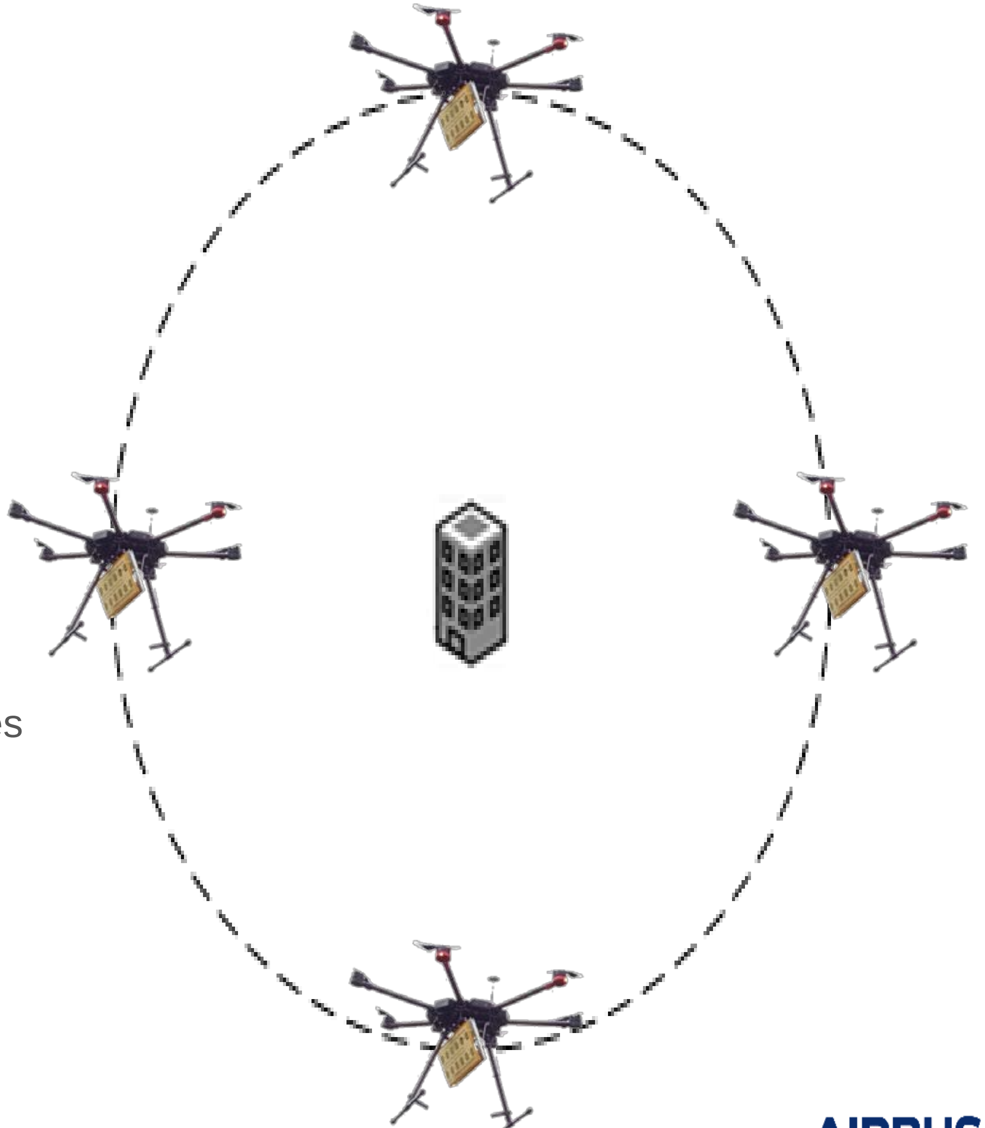
Conclusions and way forward

Conclusions

- Commercial drones provide a useful platform for rapid prototyping of novel sensor concepts as payload/range limitations are offset by cost, and ease of use
- Conventional SAR imaging has been demonstrated

Way forward

- Demonstration of tomographic imaging
- Demonstration of the use of multiple drones to build up single tomographic image
- Extension of payload modes/functionality



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