QUALCOMM®

Leading the world to 5G: Evolving cellular technologies for safer drone operation

September 2016

Enabling safer, more autonomous drones

1. 4G/5G cellular and on-board intelligence enable safe, consumer and commercial drone deployments
2. Optimizing LTE networks for safe, low-altitude drone operation beyond visual line-of-sight
3. 5G will enable wide scale deployments of mission-critical drone use cases

Cellular technologies enable safe, consumer and commercial drone deployments

Our vision for safe drone operation

Enabled by cellular connectivity and on-board intelligence

Safe, autonomous navigation

Autonomous visual navigation

Connectivity for safe operation

Secure, coordinated, massive deployments

Controlled Airspace coordination

Fleet management

A growing set of use cases and capabilities

Surveillance and 4K videography

Delivery and rescue missions

Cellular connectivity will be key for command and control, media sharing and autonomous flying

Requires new levels of connectivity and intelligence

Cellular connectivity

Safety enhancement for autonomous operation

Media sharing and payload status updates

Safety and operational communication for beyond operator's visual line of sight (BLOS)

Fail-safe link in the operator's visual line-of-sight

On-board intelligence

Professional videography

Autonomous navigation

Machine Intelligence

Computer vision

High-fidelity sensor processing

Precise localization

Enabling

A growing set of consumer and commercial drone use cases

Flying cameras

Consumer flying cameras

Movies and news media

Real estate

Delivery

Package delivery

Transport of medicines and vaccines

Public safety

Emergency services

Cellular coverage for first responders

Search and rescue

Agricultural

Crop visual inspections

Automated planting

Livestock tracking

Inspection

Critical infrastructure inspection (e.g. cell towers, bridges)

Inspection of hard-to-reach assets (e.g. oil & gas, wind turbines)

Cellular is well suited for drone operation

Ubiquitous coverage

Established networks serving billions of connections worldwide

High reliability and QoS

Managed services based on licensed spectrum

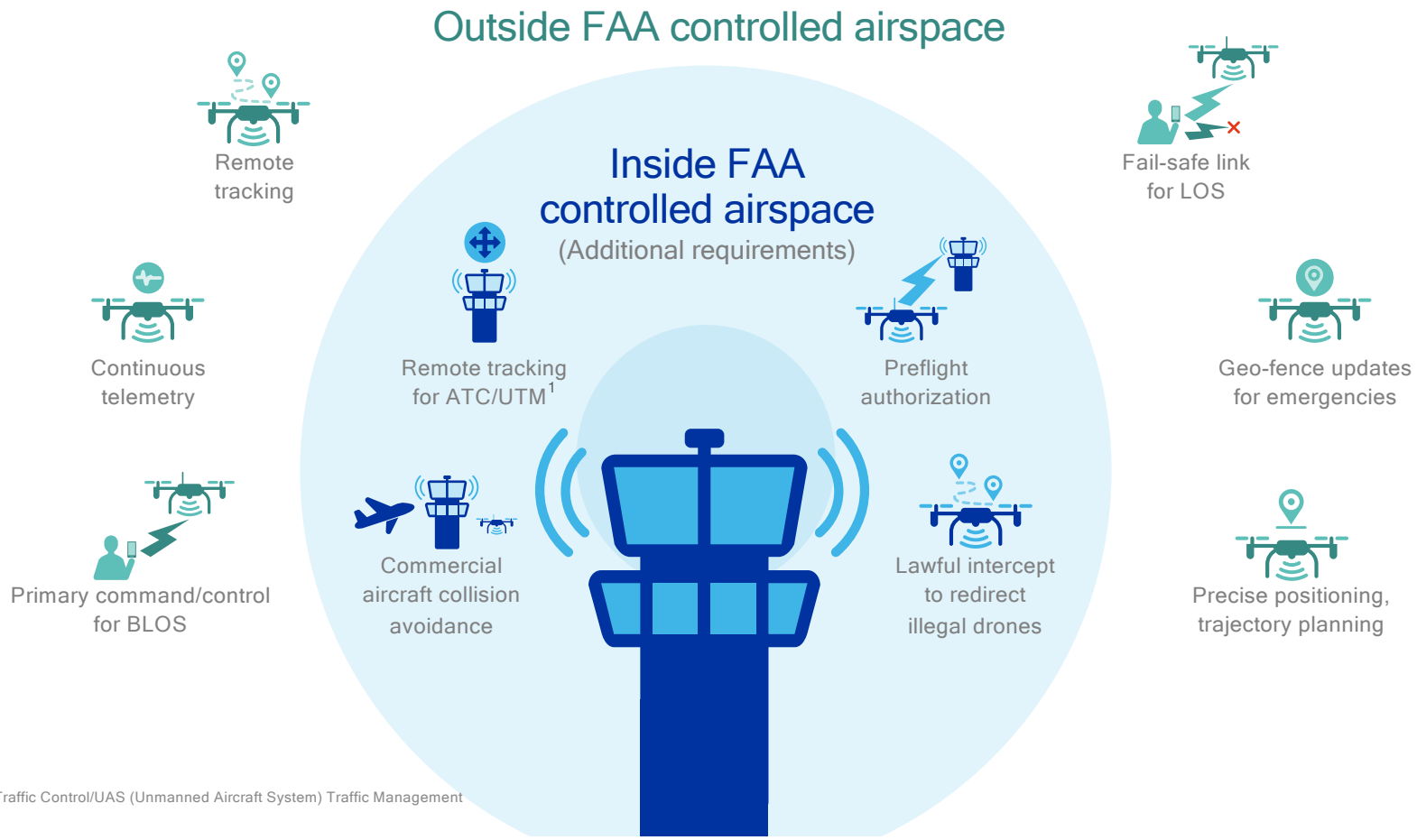
Robust security

To support reliable command and control, while protecting network integrity

Seamless mobility

Enabling continuous connection as drone travels

Cellular supports various drone communication needs



1 ATC /UTM = Air Traffic Control/UAS (Unmanned Aircraft System) Traffic Management

Advancing drone technology development

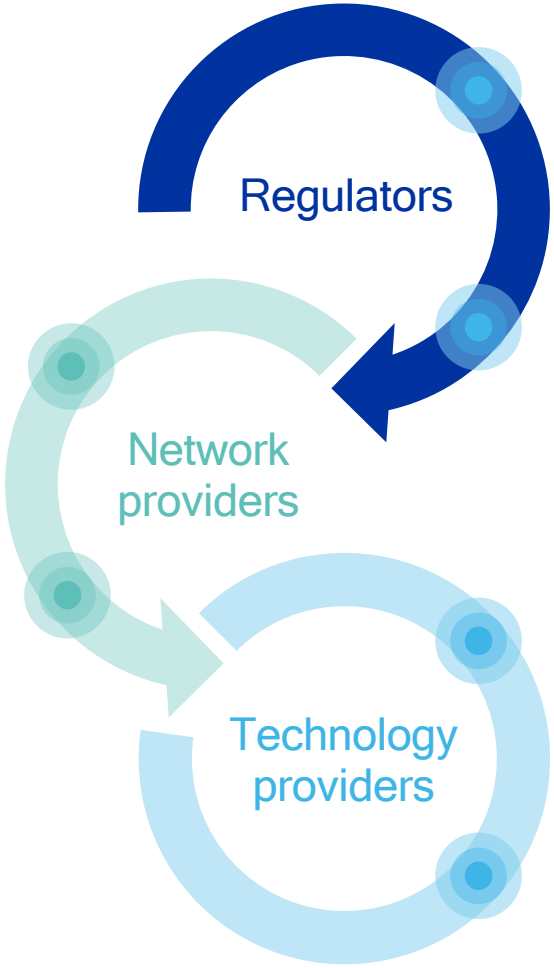
Collaboration with regulators, network, and technology providers

Optimize existing networks

Provide network coverage, performance metrics, and manage coexistence with ground smartphone and IoT UEs

Evolve network technologies

Evolve existing networks and help guide technology advancements



Safety and performance standards

Develop national drone standards (e.g. centralized management enabled by LTE)

Registration and licensing programs

Create registration and licensing programs for commercial drones and their operators

Develop on-board intelligence

Safe, autonomous operation using sensor and camera processing, location, security, computer vision, and machine learning

Enable reliable communications

Take advantage of existing cellular quality of service and guide technology advancements of LTE and 5G

Optimizing LTE networks for safe, low-altitude drone operation

Qualcomm is accelerating drone technology development

Testing drone operation over commercial LTE networks

Optimize LTE networks

Promote use of commercial cellular networks for drones, without impacting terrestrial devices

Inform regulators

Help inform positive developments in drone regulations

Accelerate 5G development

Specifically for massive deployments of mission-critical drone use cases

Qualcomm UAS Flight Center

Controlled Airspace Class B

- 24 hours pre-approval to test
- Start and Stop notification
- Continuous ATC communications/coordination

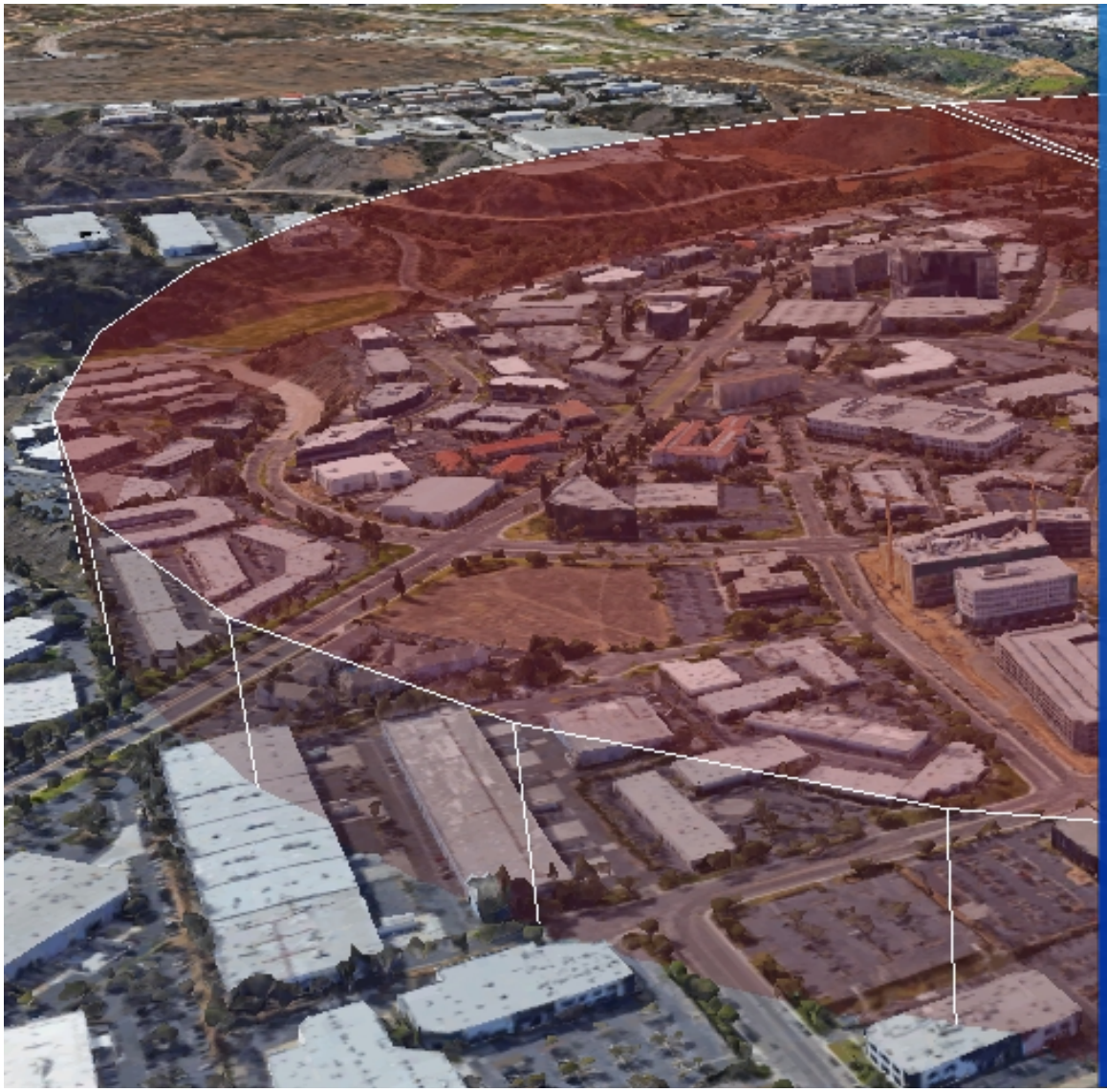
Expanding flight operation

- FAA approval expanded since March 2016
- Increased maximum altitude from 200ft to 400ft AGL[1]
- Increased operation area from 0.15 nautical mile radius to 0.5 nautical miles

Wide area LTE testing

- 1 to 2 mile flights over commercial LTE network
- Wide area with multiple base station coverage
- Multi-band and multi-altitude tests

1 Above Ground Level

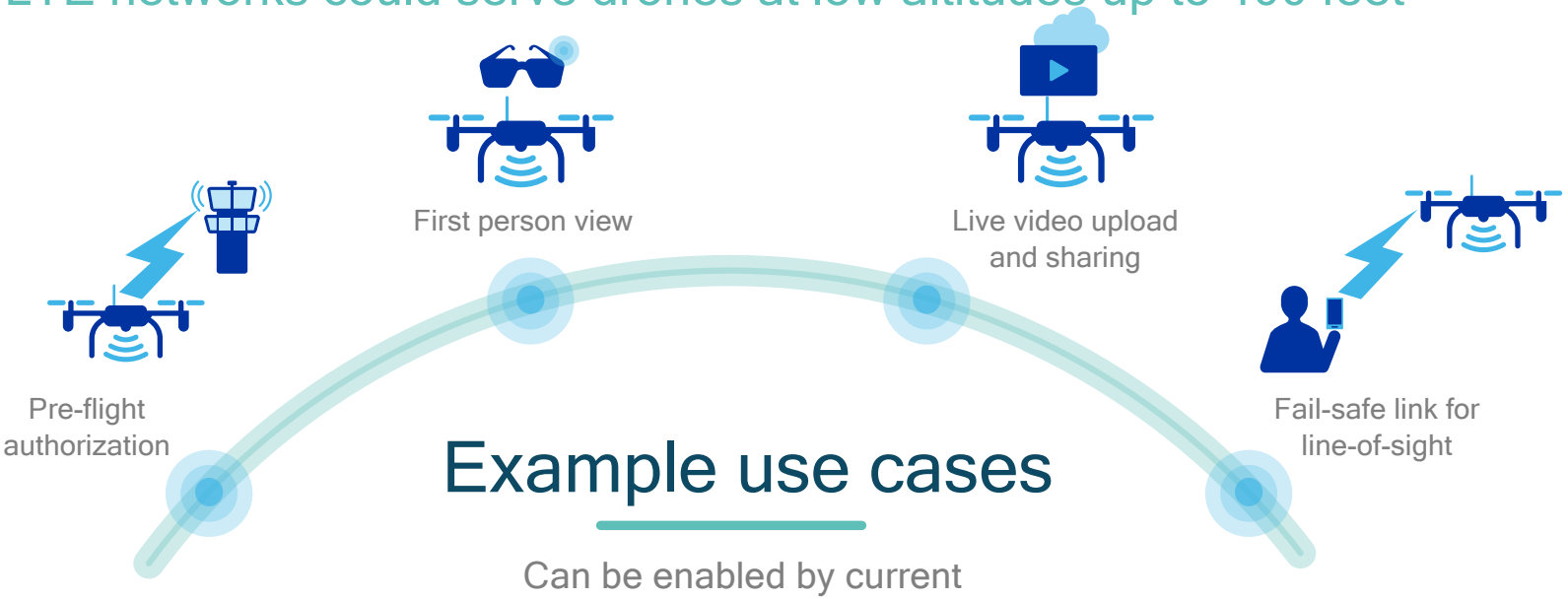


FAA-authorized UAS Flight Center and test environment

The center contains “real world” conditions mixed with a commercial, residential, rural and FAA controlled airspace

Early findings from testing over commercial LTE networks

Today's LTE networks could serve drones at low altitudes up to 400 feet[1]



Example use cases

Can be enabled by current LTE networks

Coverage at altitude

Drones at altitude are served by multiple base stations on different frequencies, providing good RF link margin - despite antennas pointing down

Mobility

Drones demonstrated seamless handovers between different base stations during flight with zero link failures.

1 5G will enable wide scale deployments of mission critical drone use cases at all relevant altitudes

Drones are well served by multiple base stations up to 400ft

However, increased interference at higher altitudes impact link quality

Stronger reference signal

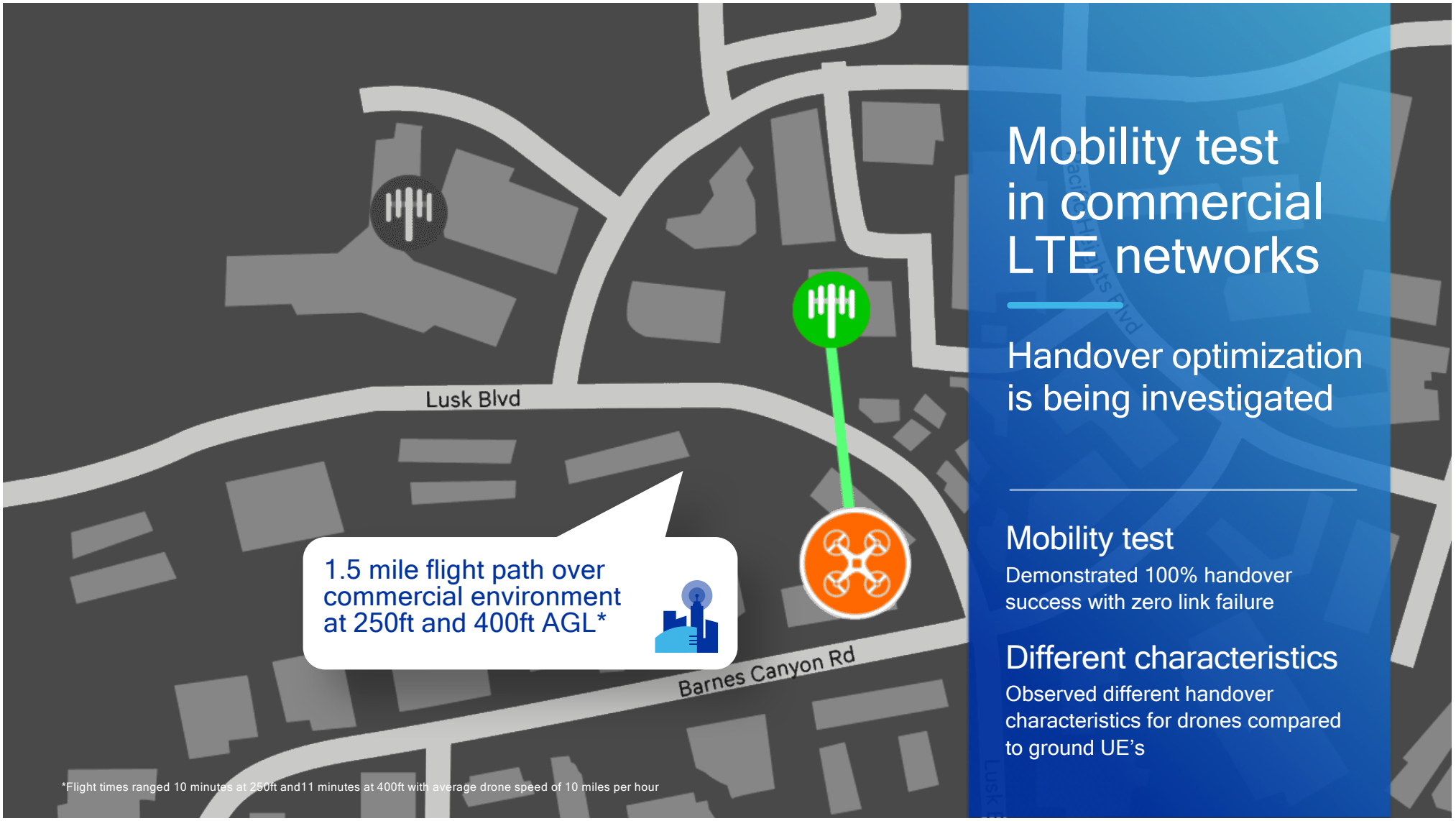
At higher altitudes, observed stronger Reference Signal (RS) received by the drone from multiple neighboring base stations

More base stations

At higher altitudes, the drone is able to detect base stations at further distances when compared to ground UEs

Number of neighbor base stations detected by a drone

	Frequency bands				Neighbor distance (miles)		
Altitude	700 MHz	1700/2100 MHz	1900 MHz	Total per Band	700 MHz	1700/2100 MHz	1900 MHz
400ft	7	5	6	18	11.5	1.6	3.16
300ft	4	7	5	16	7.1	5	1.66
200ft	6	5	7	18	11.5	1.6	1.66
100ft	7	4	6	17	9.9	1.6	1
Ground	4	4	2	10	1.6	1.6	1



*Flight times ranged 10 minutes at 250ft and11 minutes at 400ft with average drone speed of 10 miles per hour

Mobility test in commercial LTE networks

Handover optimization is being investigated

Mobility test

Demonstrated 100% handover success with zero link failure

Different characteristics

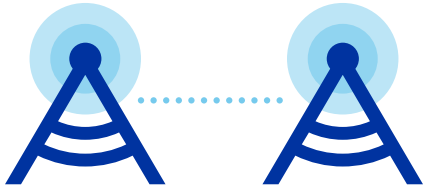
Observed different handover characteristics for drones compared to ground UE's

Further optimizing LTE networks for drone operation

Interference mitigation

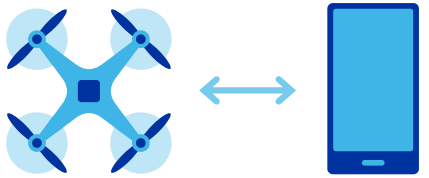
Manage interference received by the drone from high number of “neighbor” base stations radiating effectively up to 400 feet AGL

Handover optimization



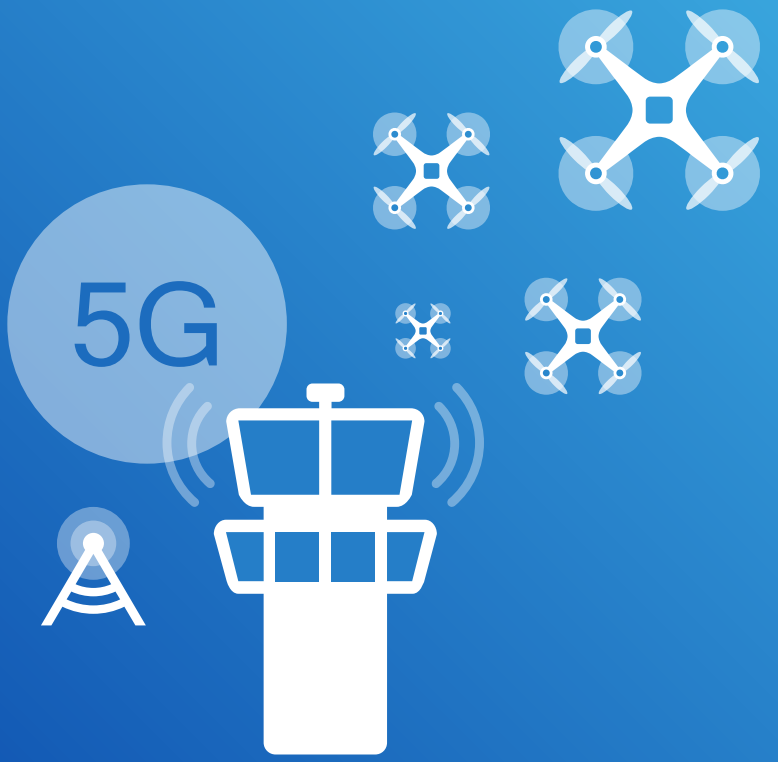
As drone’s handover behavior is different than ground UE’s, network optimization of handover may be needed

LTE drone specific requirements



In order for the network to optimize service for drones, the network may need to be able to distinguish a drone from a ground UE

5G will enable wide scale deployments of mission-critical drone use cases



A unified connectivity fabric

5G

Enhanced mobile broadband

- Multi-Gbps data rates
- Extreme capacity
- Uniformity
- Deep awareness

Mobile devices

Networking

Mission-critical services

- Ultra-low latency
- High reliability
- High availability
- Strong security

Automotive

Robotics

Health

Massive Internet of Things

- Low cost
- Ultra-low energy
- Deep coverage
- High density

Wearables

Smart cities

Smart homes

Unified design for all spectrum types and bands from below 1GHz to mmWave

Leveraging 5G mission critical and massive IoT capabilities

Wide scale deployments

Uniform throughput

Scaling up to multi-Gpbs with consistent user experience; wider bandwidths, and massive MIMO

Coverage at all relevant altitudes

Uniform coverage with reliable mobile broadband at different altitudes and speeds; optimized handover

Serving numerous devices

More efficient and reduced amount of signaling, such as device centric mobility

Direct Communication

Direct drone-to-drone communication, multi-hop and relays for safety and extended coverage

Mission critical

Ultra-high reliability

Ultra-reliable transmissions that can be time multiplexed with nominal traffic through puncturing

Strong e2e security

Security enhancements to air interface, core network and service layer

Ultra-high availability

Multi-connectivity/redundant links for failure tolerance and extreme mobility

Low end-to-end latency

Faster, more flexible frame structure and grant-free uplink access (e.g. RSMA)

Enabling wide scale deployments of mission critical drone use cases

Sample use cases

Collaboration for search and rescue missions

UAV[1] collaboration to search for a victim in a rescue mission, or suspect from a crime scene, or swarm to move an object

Coordinated operation for autonomous drones

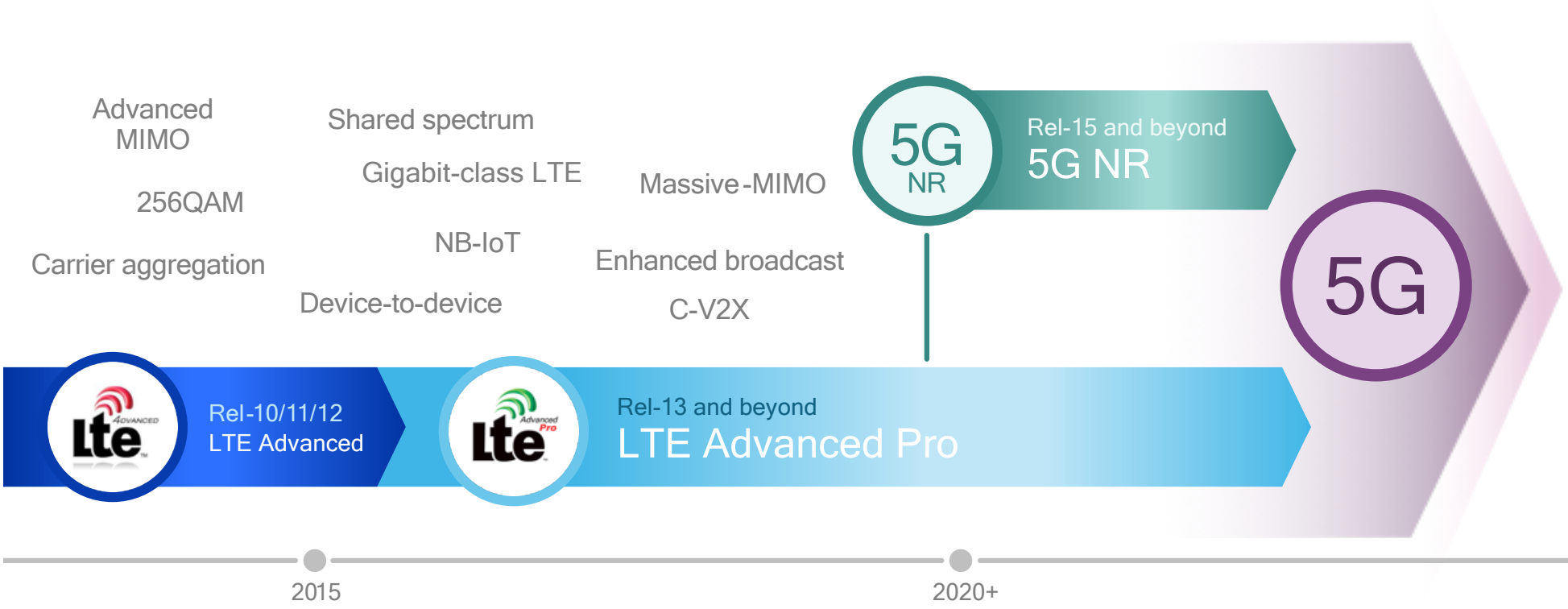
Reliable delivery of autonomous drone data for air traffic management and integration of UAS[2] into National airspace

Aerial, 360 Virtual Reality for tours and events

Users in an event or tour use a cellular connected HMD to see what the drone is capturing real time

1 Unmanned Aerial Vehicle; 2 UAS: Unmanned Aerial System

The path to 5G includes a strong LTE foundation



Note: Estimated commercial dates. Not all features commercialized at the same time

Accelerating drone technology development

Qualcomm provides the connectivity fabric for drones

Supporting different UAV communication needs even BLOS

Offering different Wi-Fi chipsets for drones

Dedicated and integrated chipsets for remote control and first person view

Optimizing LTE for safe drone operation

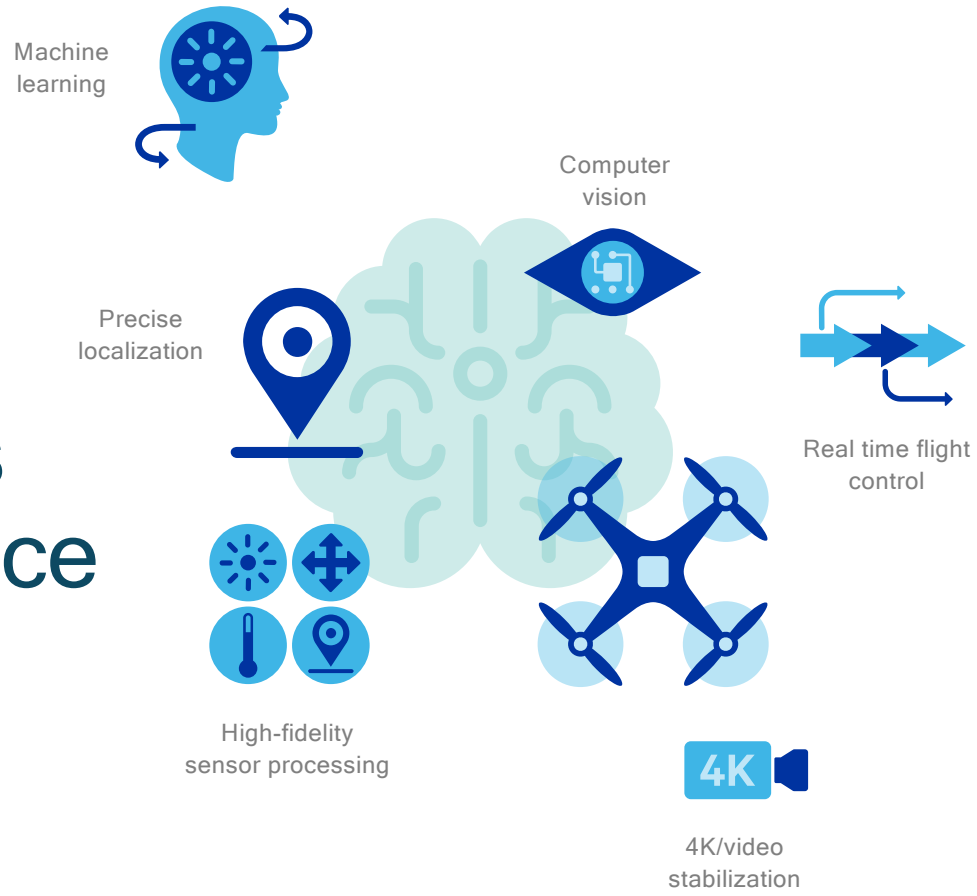
Leveraging our FAA-authorized test environment, representing “real world” conditions

Accelerating 5G technology development

Supporting 5G specifications within 3GPP, specifically for massive deployments of mission-critical drone use cases

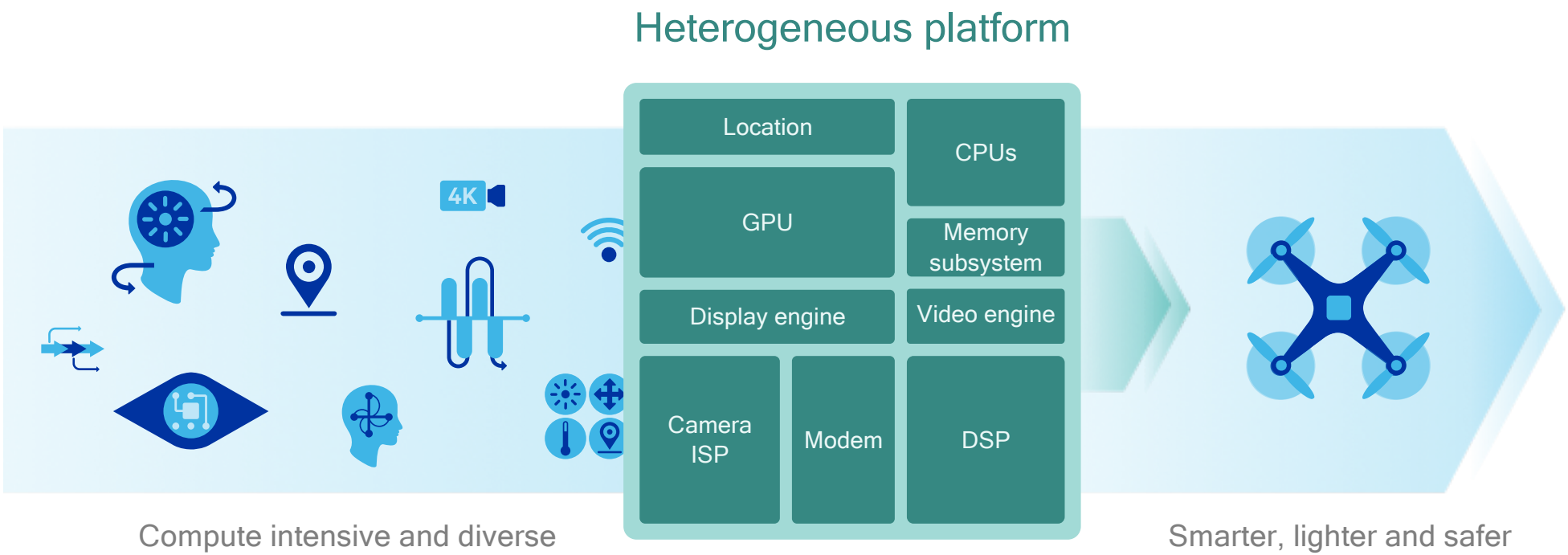
Delivering new levels of on-board intelligence and integration

Bringing cognitive technologies to life



Bringing together essential technological innovations

On a highly optimized heterogeneous computing platform



Compute intensive and diverse characteristics

Smarter, lighter and safer autonomous drones

Enabling new experiences on Snapdragon Flight Platform

Leading commercial drone

5.8GHz RF PCB

Main PCB

Video Transmitter PCB

GPS Receiver PCB

Camera PCB

Wi-Fi PCB

Flight Controller PCB

7 circuit boards = 189 cm^2

Qualcomm®
Snapdragon Flight™ platform

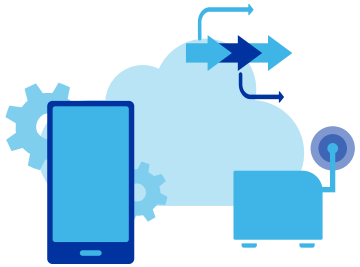
1 Snapdragon Flight = 23.2 cm^2

Qualcomm, leading the world to 5G

Investing in 5G for many years—building upon our leadership foundation

Wireless/OFDM technology and chipset leadership

Pioneering 5G technologies to meet extreme requirements



End-to-end system approach with advanced prototypes

Driving 5G from standardization to commercialization

Leading global network experience and scale

Providing the experience and scale that 5G demands

In summary

Cellular benefits

4G/5G cellular and on-board intelligence enable safe, consumer and commercial drone deployments

LTE optimization

Qualcomm is optimizing LTE networks for safe drone operation beyond line of sight—using the FAA authorization

5G mission critical

5G will enable wide scale deployments of mission-critical drone use cases

Qualcomm leadership

Integration of our advanced technologies in small form factor to enable current and future UAV services in controlled and uncontrolled airspace environments

Thank you

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