HIGH ALTITUDE PLATFORMS ('HAPs')

"The Future for Communications?"

Tim Tozer

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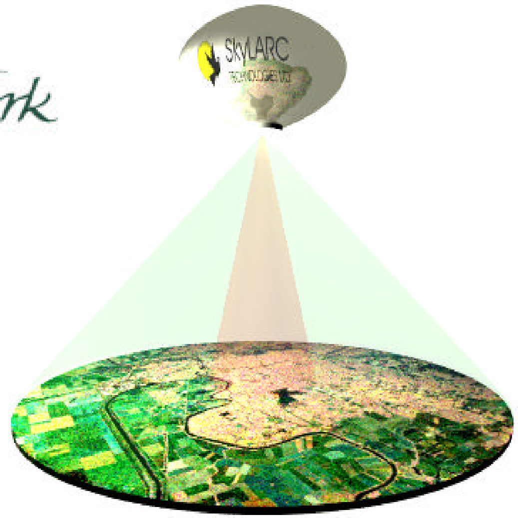

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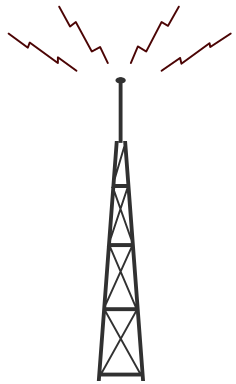
1/ Wireless Communications

- Demand for communications growing worldwide
  - 'Multimedia'
    - » Convergence of Internet, Video-on-demand, TV, Telephony, etc.
  - New entrants and new value-added services
    - » Competition
  - Services for under-developed or remote regions
  - Need for mobility



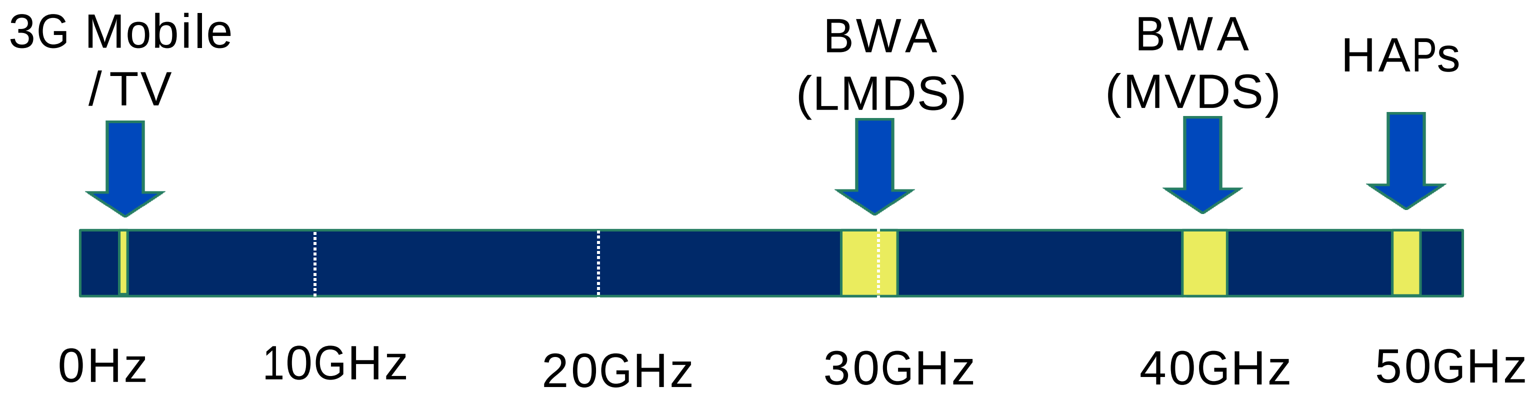
- Wireless provides solutions:
  - 'Last mile'
    - » Expensive and disruptive to replace by cable
  - Capacity for broadband services
    - » Often not met by existing cable
    - » ISDN limited
    - » xDSL limited in scope and capacity
  - Rapid deployment
  - Often the only viable bearer

Broadband Wireless Access (BWA)

- 'Multimedia' wireless delivery
- LMDS services: Video, Internet, Telephony etc
- Business/Home application
- High system availability target, e.g. 99.99%?
- High data rate, e.g. bursting to 155MBit/s
- "Bandwidth on Demand"

Demands on the Radio Spectrum

- Need for Bandwidth means higher frequencies
  (Roughly available BW $\propto f$?)
- LMDS bands @ $\geq$ 28 GHz (Varies between regions)

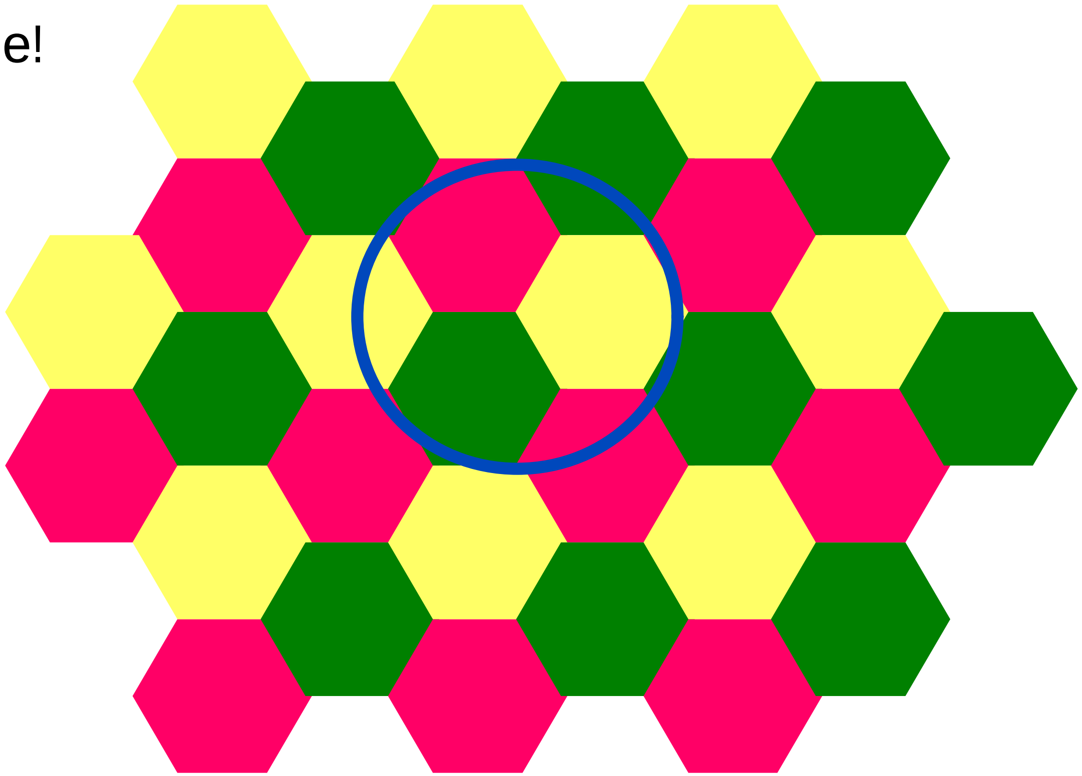


– Good coverage requires extensive base-station infrastructure

– More demanding at higher frequencies, due to LOS propagation

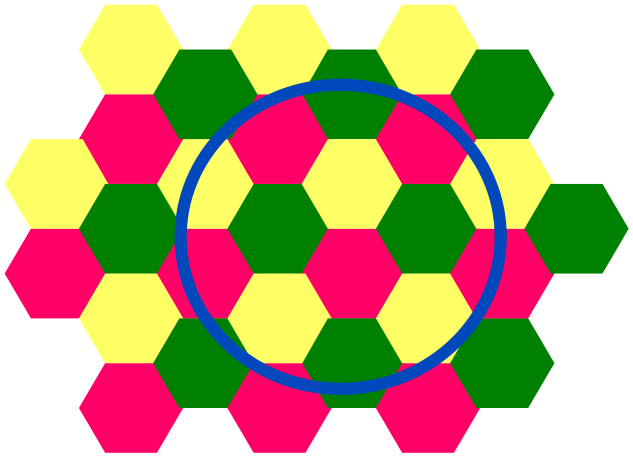
Wireless Cellular Principles

- Frequency Re-use Structure
- Ultimately Interference Limited
- Or if not, it should be!



Wireless Cellular Limitations

- Large overall capacity necessitates large number of small microcells
- Means many base-stations
- And associated feeder costs



Wireless Limitations /contd

Also:

- Use of *mm*-wavebands implies Line-of-Sight
- Problems with local obstructions

→ Large investment in base stations and associated feeder links

What's needed?

- **Very tall masts**?
  - Visually intrusive
- **Satellites**?
  - Very limited capacity
  - Also DELAY
- **Something else**?

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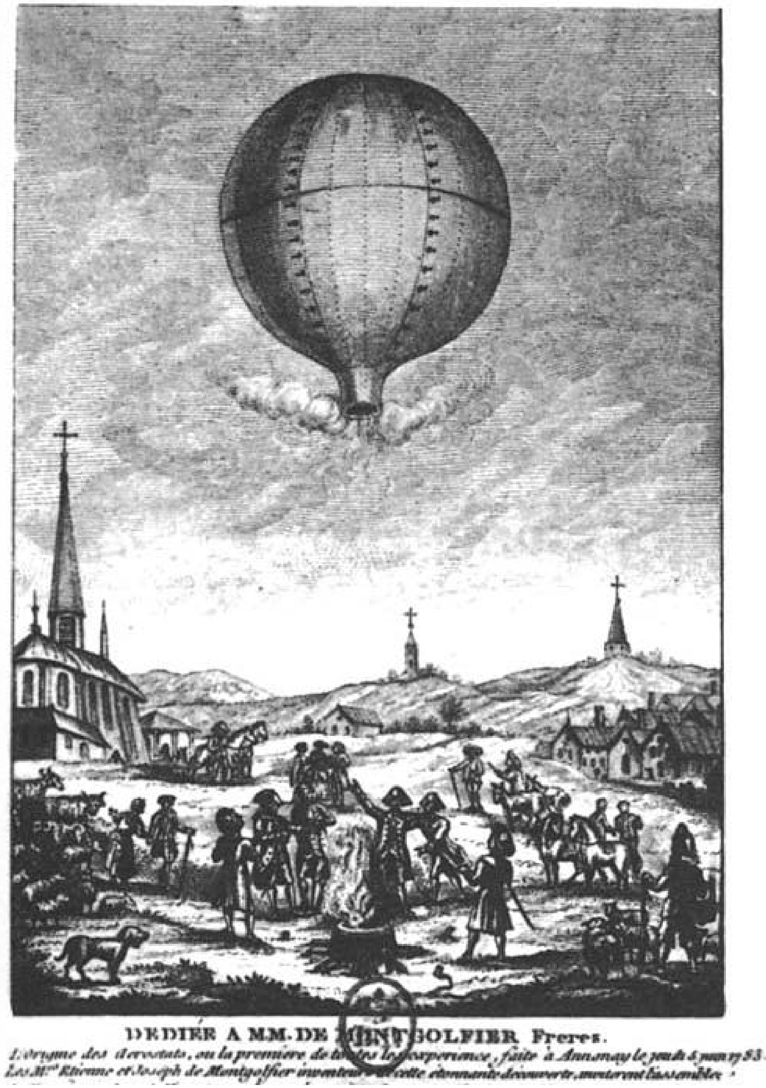
2/ Balloons → Airships

Montgolfier

1783



Hot air balloons were used for military purposes throughout the 19th century.

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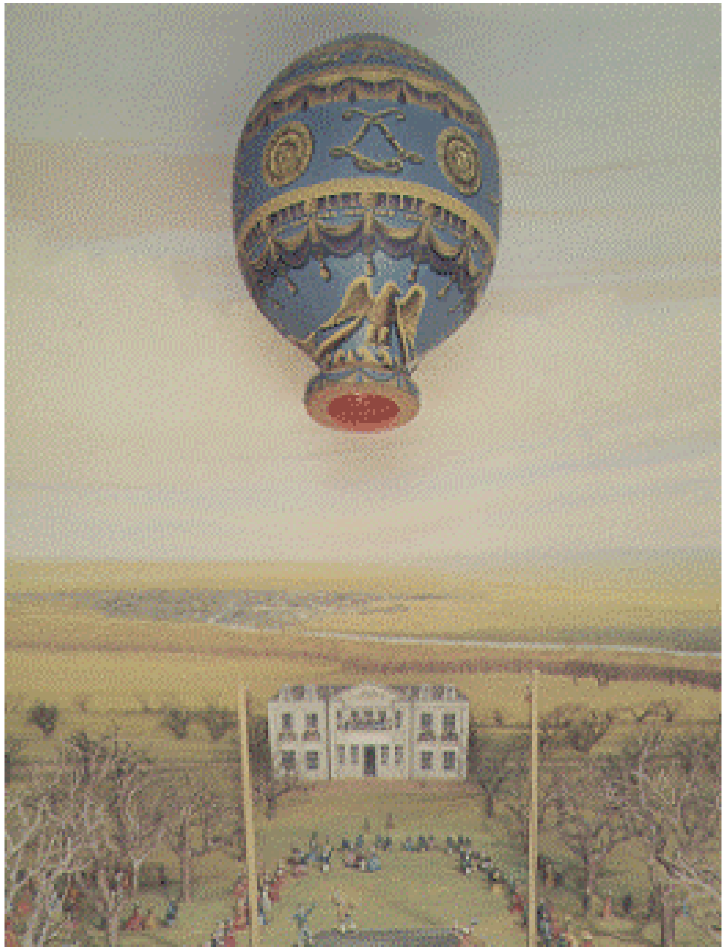
FIGURE EXACTE
ET PROPORTIONS
DU GLOBE
AËROSTATIQUE
Qui, le premier,
a enlevé
des Hommes
dans les Airs



Modern balloons

Hot Air:
Recreational & advertising

Lindstrand's Breitling Orbiter
(Helium filled)

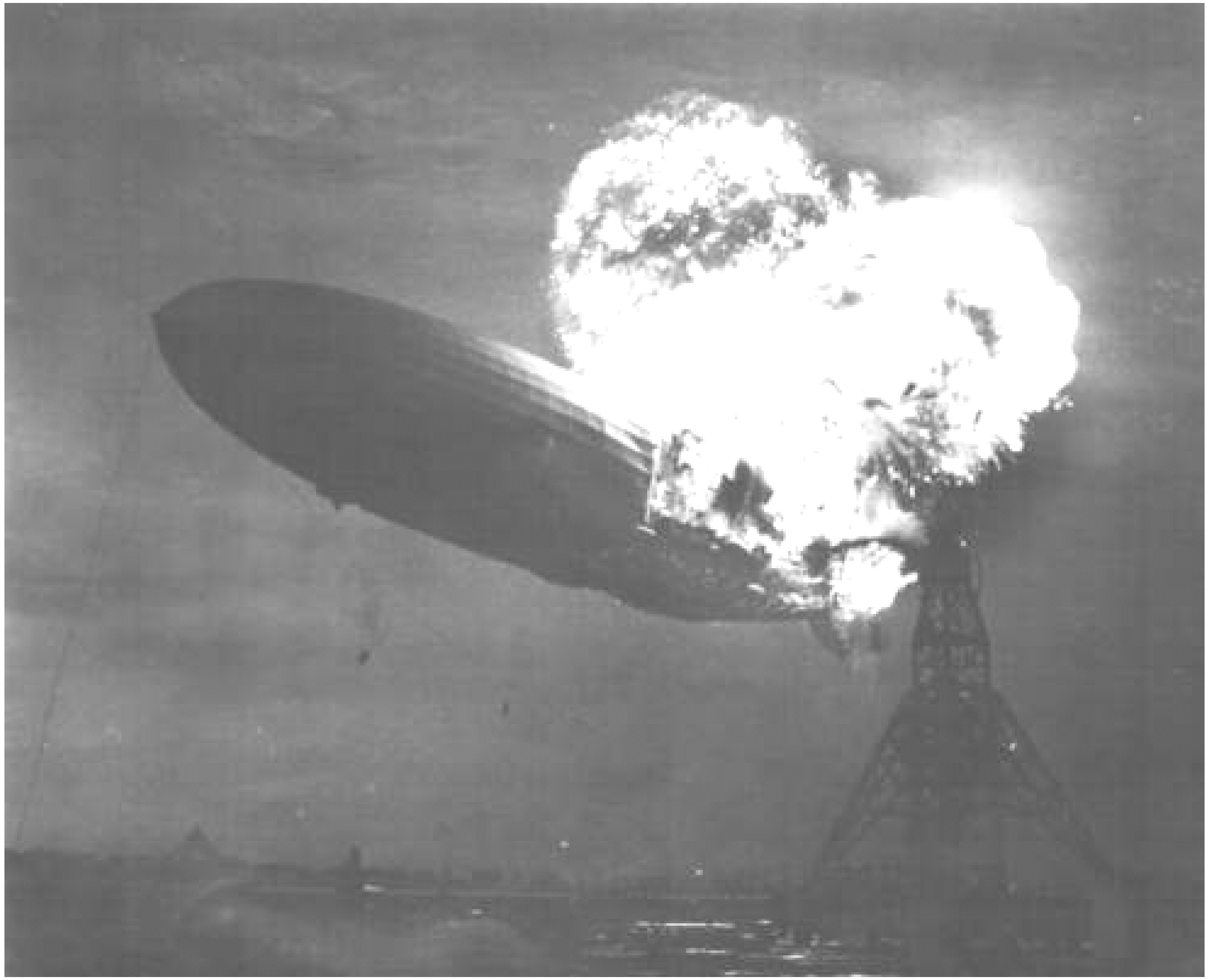
Zeppelin, 1900 onwards

'Rigid' airship

Hydrogen filled

Used for passenger transport

“Death of a dream”



Hindenburg
Disaster

Lakehurst
1938

Zeppelin re-born!

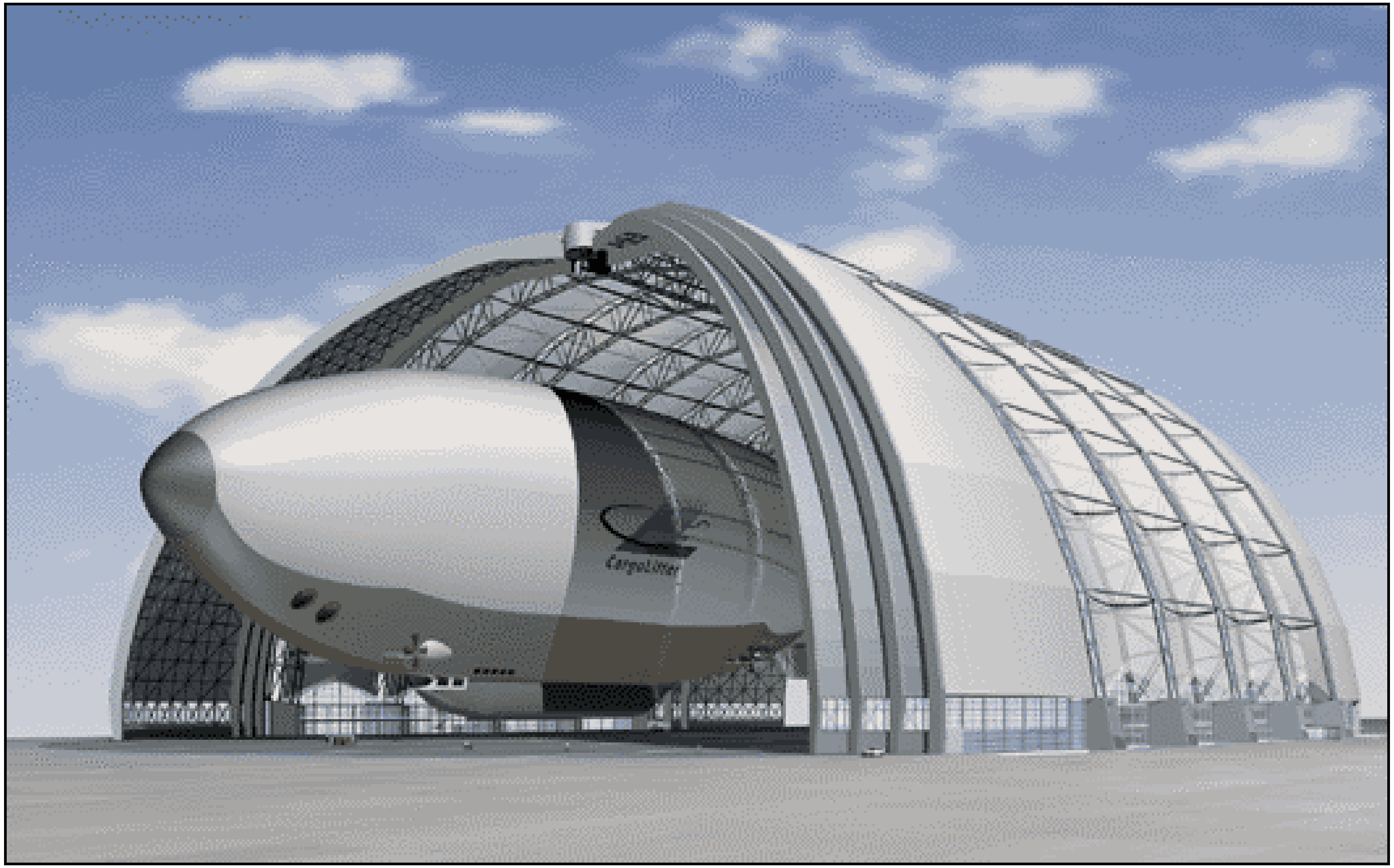
Modern semi-rigid airship,
low altitude

Helium filled

Friedrichshafen, July 2000

Planned for tourism!

CARGOLIFTER (Germany)



Airship evolution:
High Altitude Platforms ('HAPs')

• Situated 17 - 22 km altitude (up to 72,000 ft)

<u>Airships:</u>

- Solar powered
- Unmanned
- Helium filled
- Semi-rigid
- Very large!
- Mission duration up to a few years

LINDSTRAND HAP
Artist's impression

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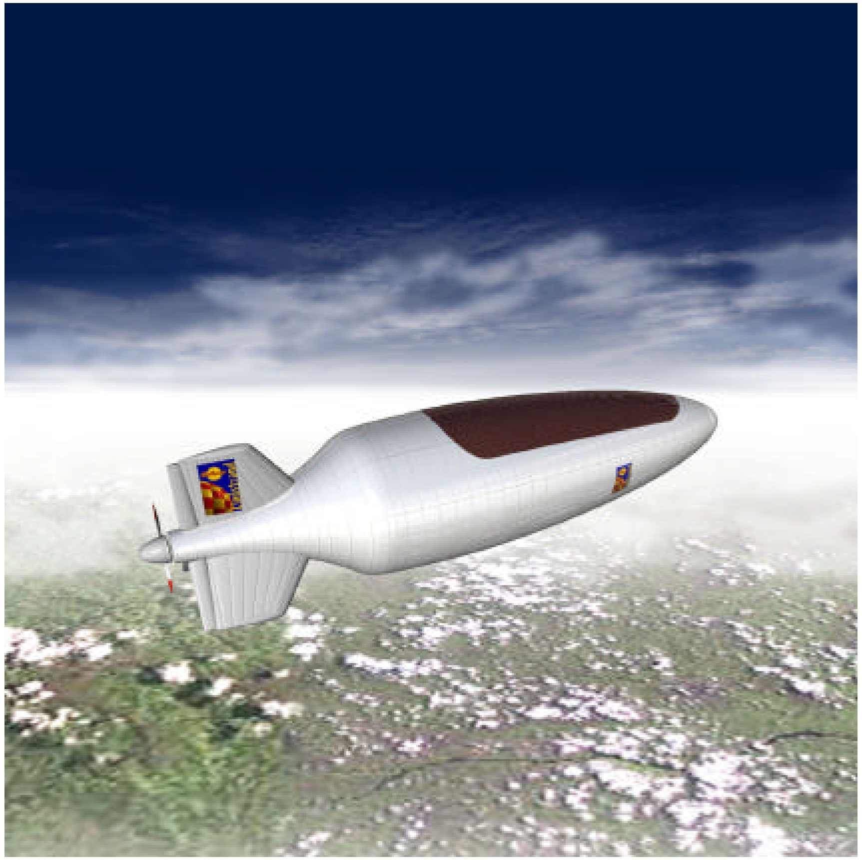
HAP Airship Enabling Technology

- Lightweight Solar Cells
  (< 400 g/m^2)

- Reliable & efficient Fuel Cells

- Materials
  - Plastic laminates
    - Resilient to UV
    - Strong
    - Helium leakproof



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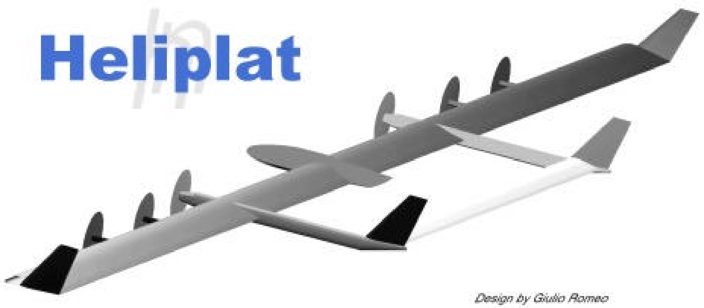
Other HAPs

Aircraft

- unmanned, solar powered or manned, conventional



Other terms:

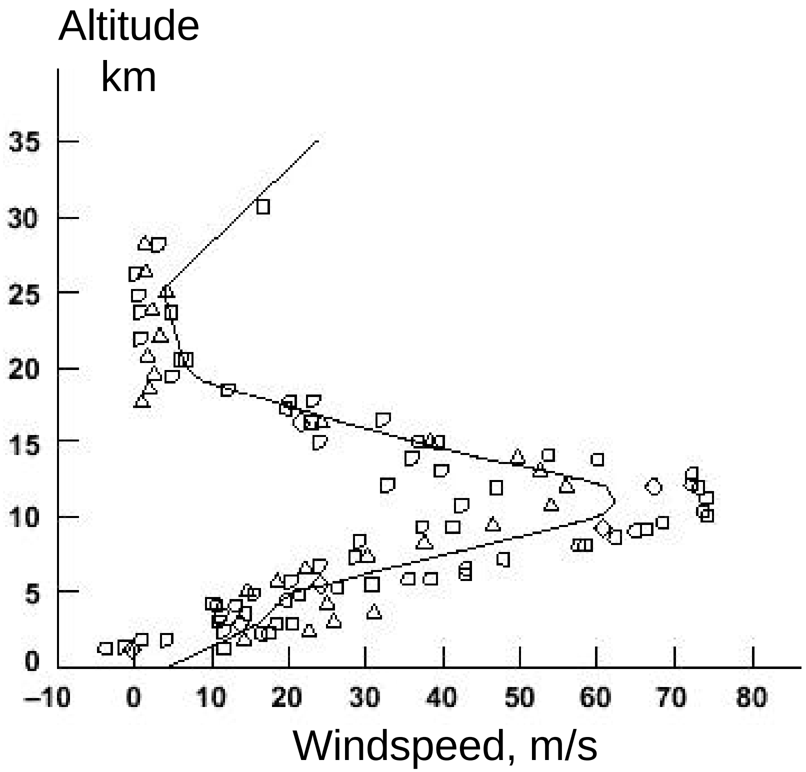
- HAAPs - 'High Altitude Aeronautical Platforms'
- HALE platforms - 'High Altitude Long Endurance'

HAPs provide a

Quasi-stationary communications relay platform

Why 20 - 22 km altitude?

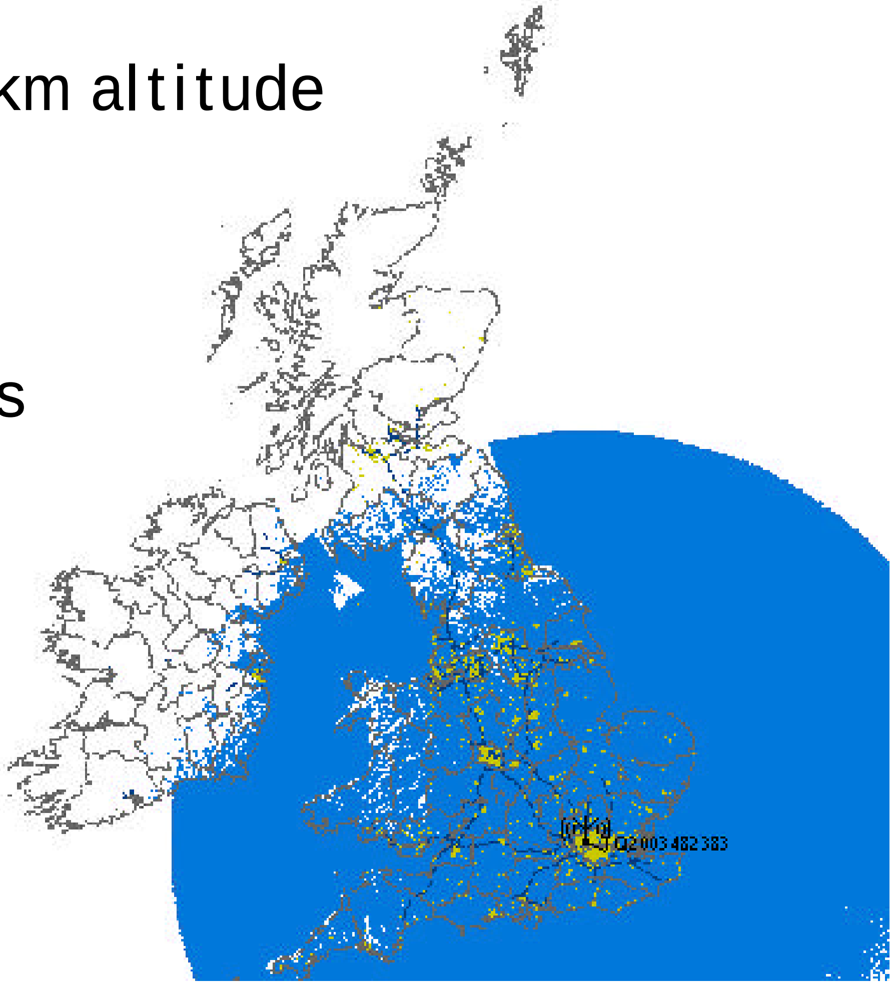
- Above aircraft
- Winds relatively mild here
  - But depends on location and season



- How far can you ‘see’?

Potentially large coverage area

- 1 HAP over London @ 20 km altitude
- Line-of-sight shown here
- Useful radio coverage less (or more) than this



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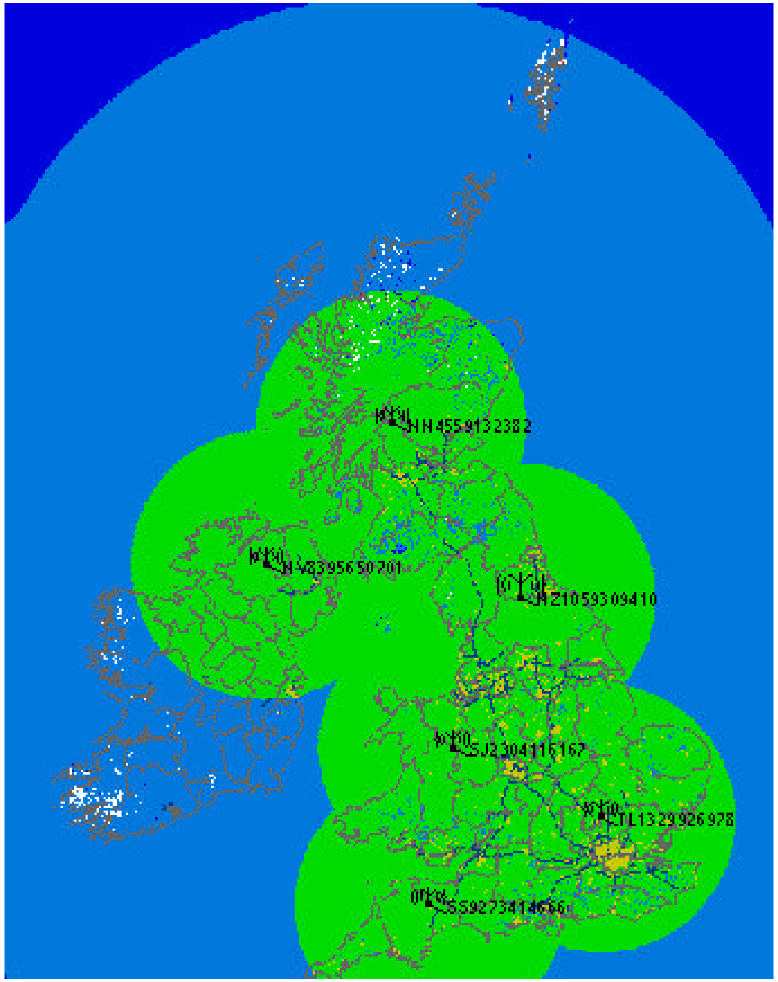
3/ HAPs for Communications

- An opportunity and a challenge



- Combine best features of Satellite and Fixed Wireless Access (FWA) services
- A very tall antenna mast?
- A very low geo satellite?
- Either individual HAPs
- Or a Network of HAPs
- (Inter-HAP links straightforward)
- Transparent or processing

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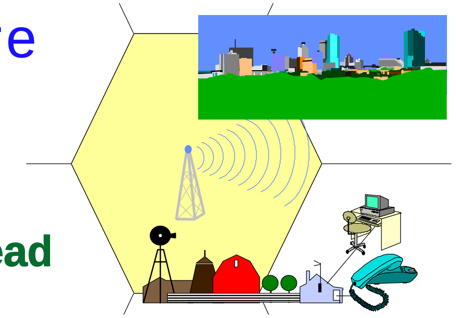
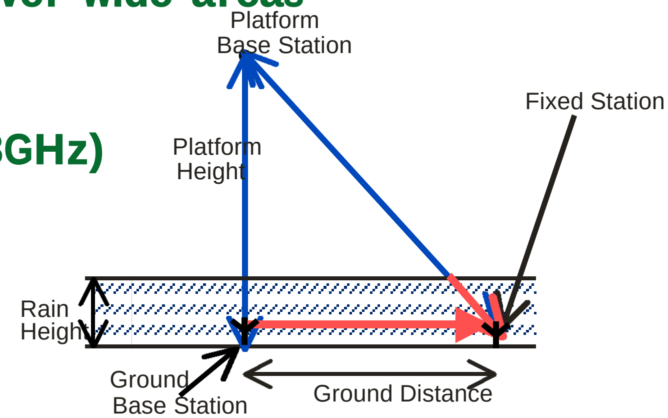
Advantages of HAPs:
(i) Compared with Terrestrial Services



- Replace extensive ground-based infrastructure
  - **1 HAP can provide multi-cellular services over area > 200 km radius**
  - **Eliminates cost, risk, site acquisition problems, environmental impact, installation/maintenance overhead**
  - **No need for local terrestrial backbone**
  - **Backhaul can be provided to where fibre is available**
- Better propagation in many scenarios
  - **Unobstructed line of sight paths**
  - **May be less affected by rain attenuation over wide areas**
- Large system capacity, through:
  - **Use of *mm*-bands (e.g. 600 MHz BW @ 48GHz)**
  - **Extensive freq. re-use**
  - **Flexible adaptive resource allocation**
- Rapid deployment



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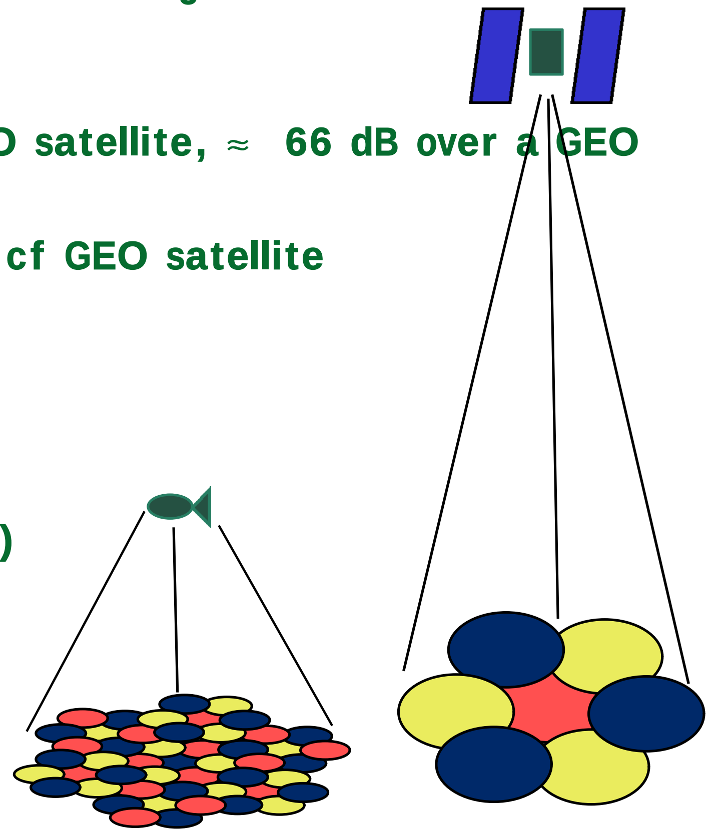
Advantages of HAPs:
(ii) Compared with Satellite Services

- Larger overall system capacity:
  - **Small spot beams (cells) readily feasible without huge on-board antennas - much better than GEO or LEO**
- Close range $\rightarrow$ good link budgets
  - **Typ. $\approx$ 34 dB range advantage over a LEO satellite, $\approx$ 66 dB over a GEO**
- Close range $\rightarrow$ low delay
  - **No problems with protocols (inc. TCP/IP), cf GEO satellite**
- Lower cost
  - **No launch vehicle**
  - **Less demanding than space systems**
- Rapid Deployment
  - **No long lead times, (cf years for satellite)**
  - **Easy upgrade and maintenance**
- Incremental deployment
  - **Can provide service with only 1 HAP: no need for a whole constellation**
- Environmentally friendly
  - **No launch vehicle/rocket**
  - **Solar powered**



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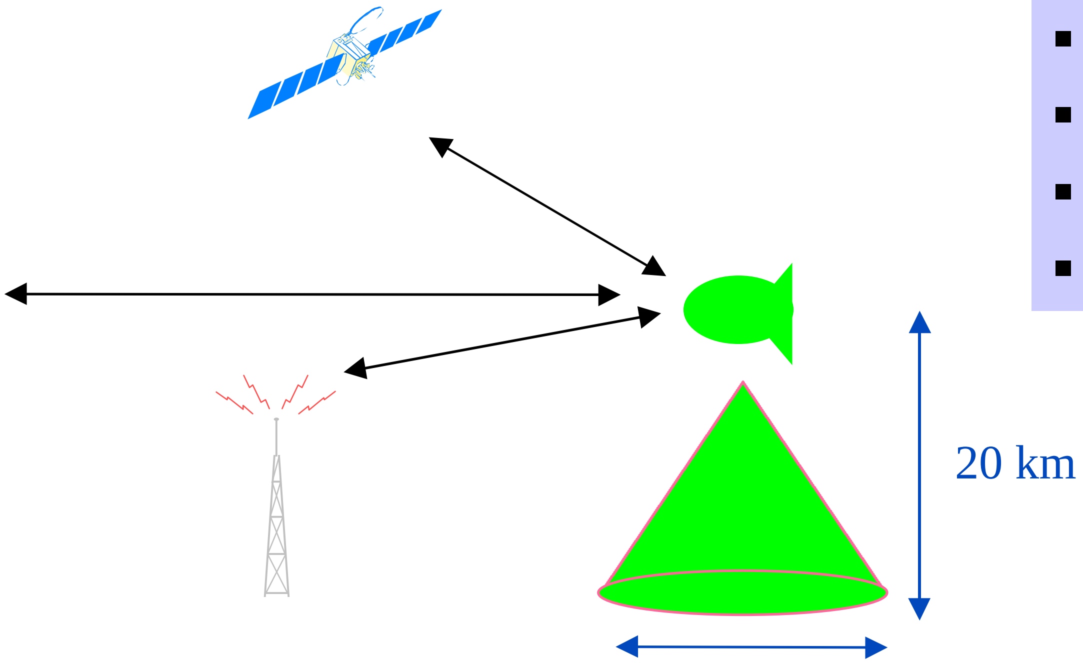
4/ HAPs Communications Illustrations

- Broadcast (TV or radio)
- Narrow-cast
- LAN Interconnect
- Internet
- Telephony
- Etc.



388 km (5° elevation),
or smaller spot-beam(s)

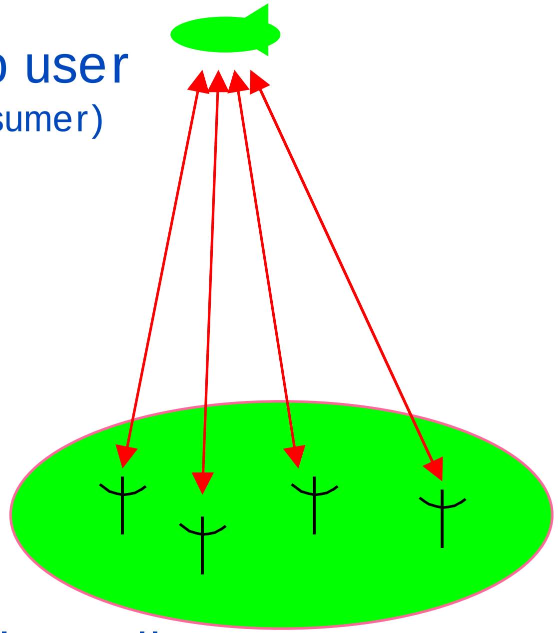
Backhaul, if needed, via:
- Terrestrial link to fibre
- Satellite
- Another HAP

Variety of topologies and services

- Can replace virtually any satellite services
- DVB format can encapsulate IP
- IP can handle speech etc.
- Can be asymmetric (low data rate inbound)

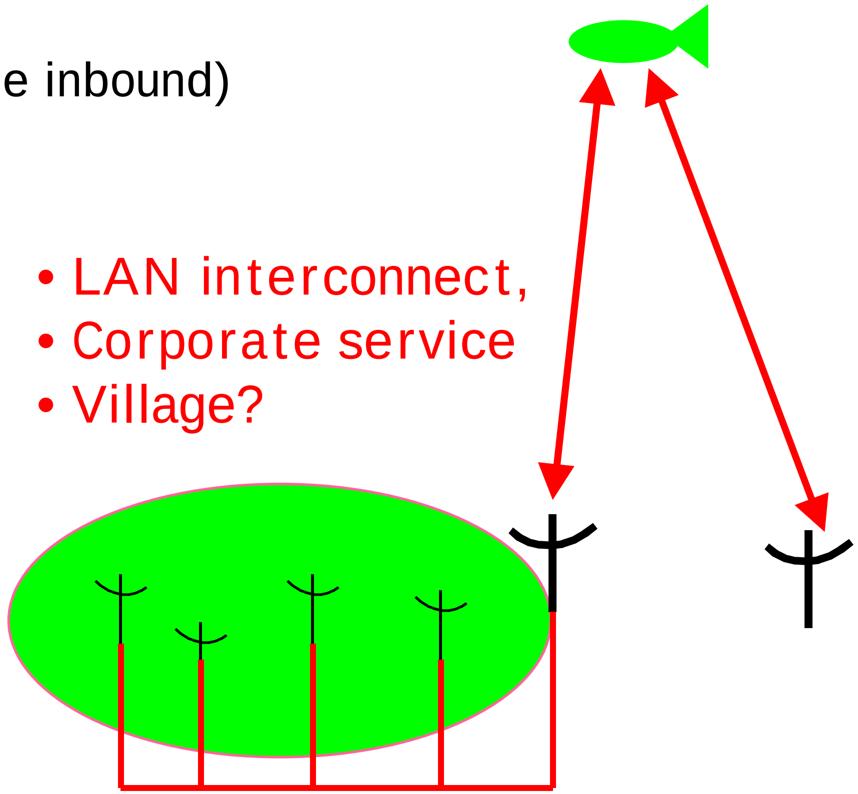
- Direct to user
(e.g. SoHo, Consumer)

- "Last mile" solution



- Needs only small fixed terminal antenna

- LAN interconnect,
- Corporate service
- Village?



LAN (wire or wireless)

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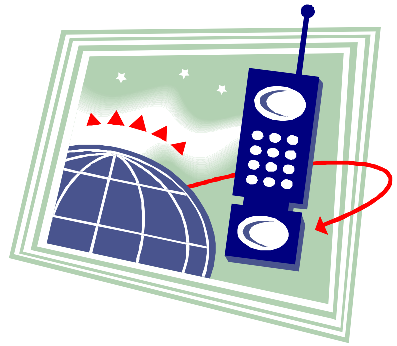
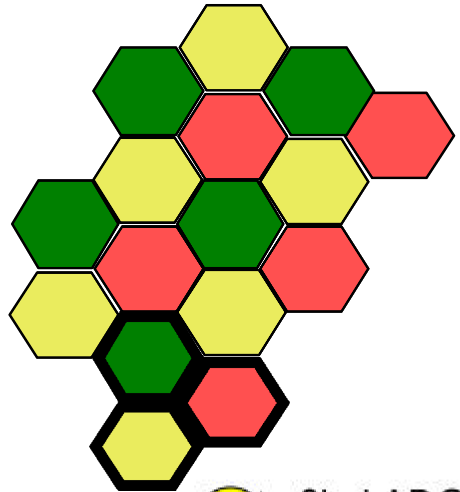
Mobile (Cellular) Services

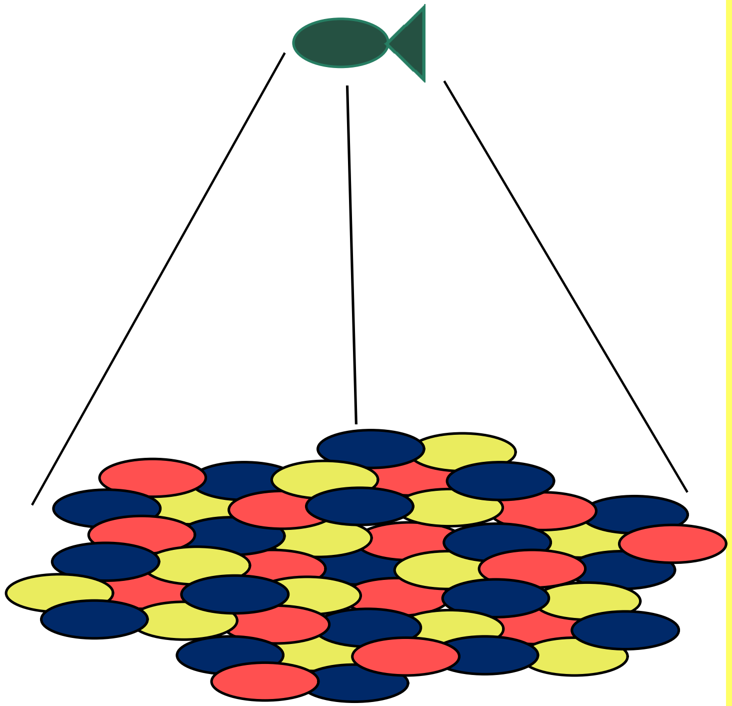


- 3G (IMT-2000/UMTS) (or 2G)
- Rapid deployment for new entrants
  or where infrastructure lacking (i.e. developing world)
- Or to serve ‘hot spots’
- No need for unsightly and costly masts
- Cellular structure with freq. re-use pattern
  - Capacity limited by Interference from co-channel cells
  - Function of beam shape & sidelobes
    (cf. ground propagation in terrestrial)
- Some issues:
  - Antennas on the HAP
  - Handover/Network issues
  - Backhaul



BWA from HAPS

Frequency Re-use with Cellular Scheme to provide large capacity



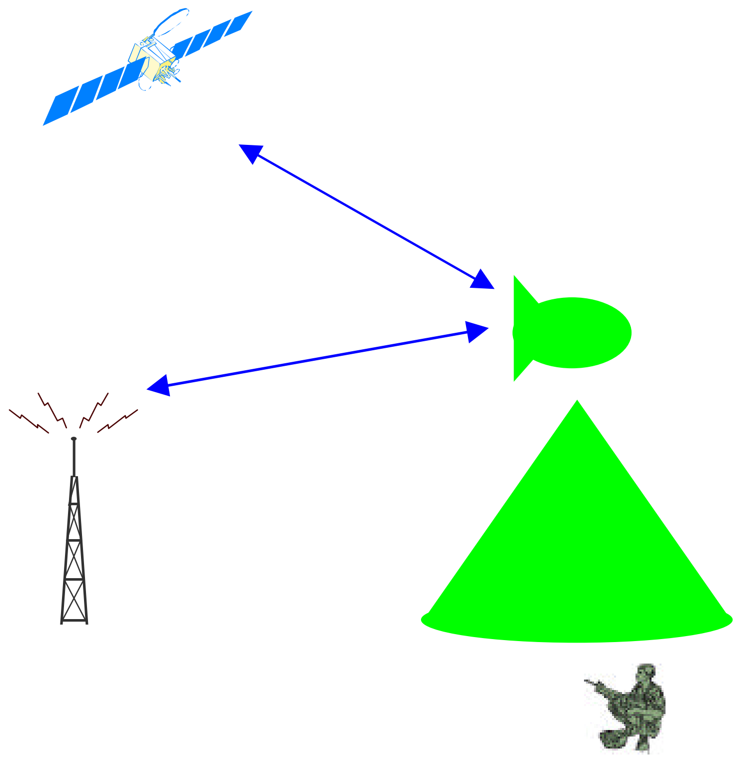
- LMDS type services
- Include TV broadcasting, Video on demand, etc. etc.
- 48 GHz (or maybe lower?)
- Small cell sizes, < 1km dia
- Potential for smaller and adaptive cells
- Allows extensive freq. re-use and high overall capacity
- HAP-based node (processing)
  - (Or transparent?)
- Terminal antennas small, maybe fixed

Military Comms with HAPs

Tactical Communications

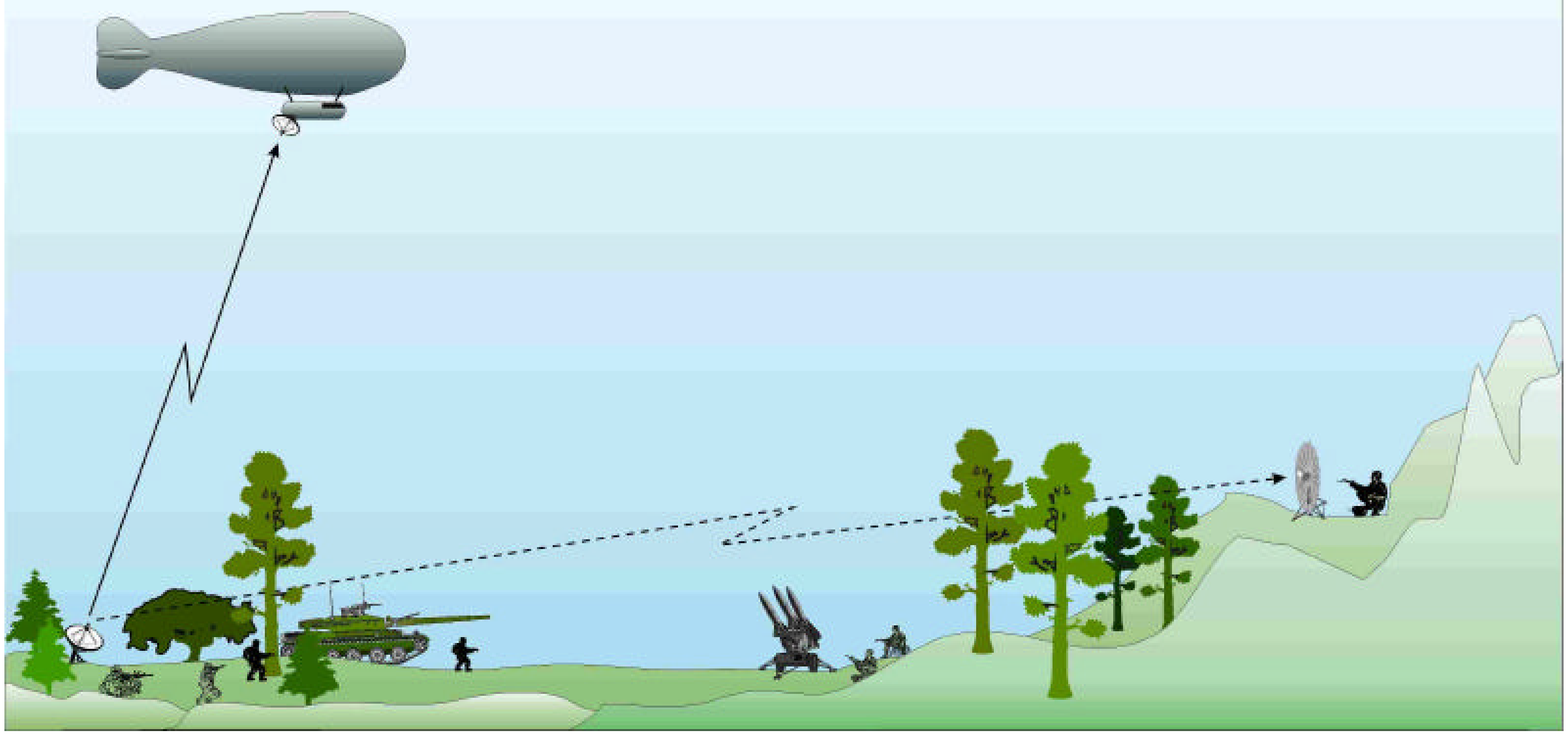
HAP/UAV ('unmanned aerial vehicle') gives:

- Tactical network Node
- or transparent relay.
- Rapid deployment
- Backhaul options:
  - terrestrial link
  - another HAP/aircraft
  - via satellite



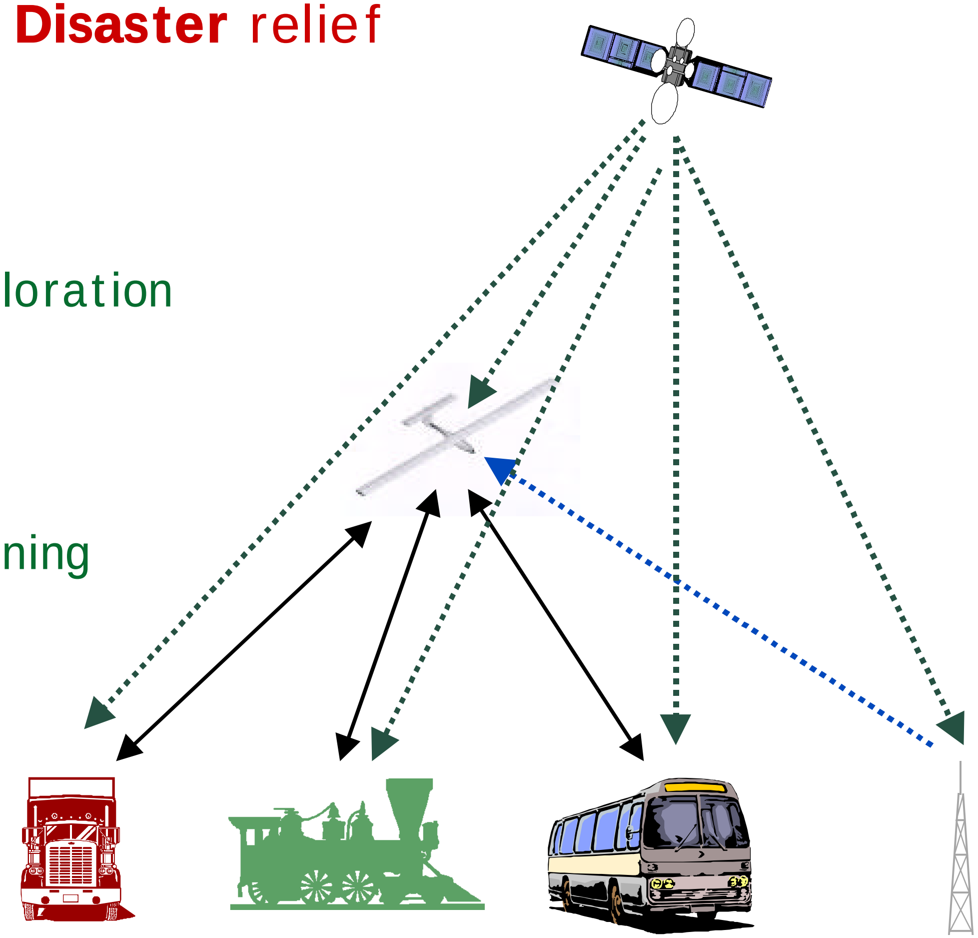
Low Probability of Intercept (LPI)

- A critical aspect for the military tactical user
- HAPs offer considerable advantages



Also with HAPs -

- **Emergency** Services and **Disaster** relief
  - Rapid Deployment
- **Niche markets**
  - E.g. oil/gas/mineral exploration
  - Or remote communities
- **Localisation/navigation**
  - Surveillance and positioning
  - Direction of arrival
  - Differential GPS



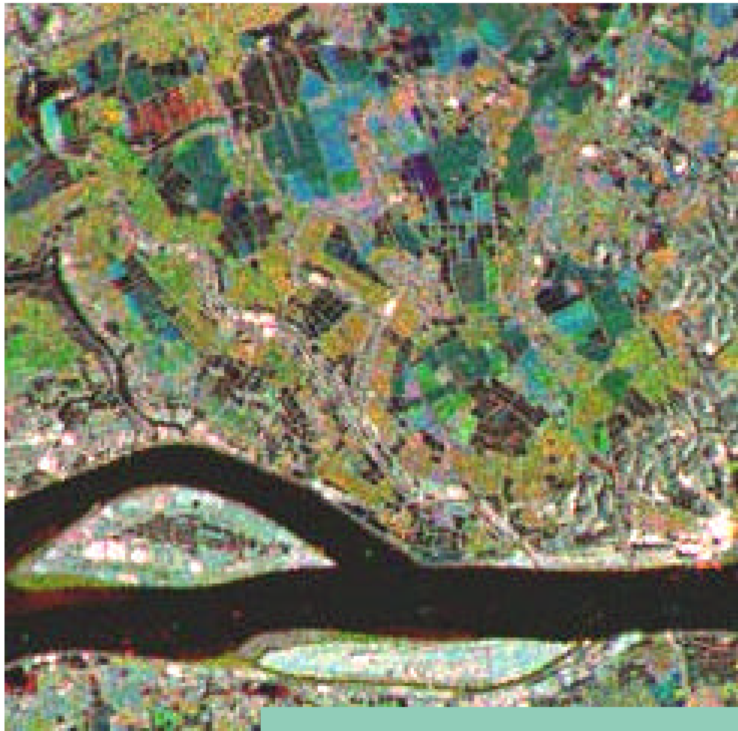
Other Applications for HAPs

Remote Sensing

Flood Detection

Seismic monitoring

Remote Sensing Applications /contd



Crop Monitoring

Traffic Monitoring & control

Regulations & Frequency allocations for HAPs

International ambivalence and uncertainty:

- Is it terrestrial?
- Is it a plane?
- Is it a spaceship?

- Regulatory issues still emerging for operations and radio allocations.

BUT:

- ITU has allocated, specifically for HAPs services, 600MHz @ 47/48GHz (shared with satellites)
- Also, authorised use of HAPS for some 3G services (around 2 GHz)

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Broadband Comparison with Terrestrial/Satellite Systems

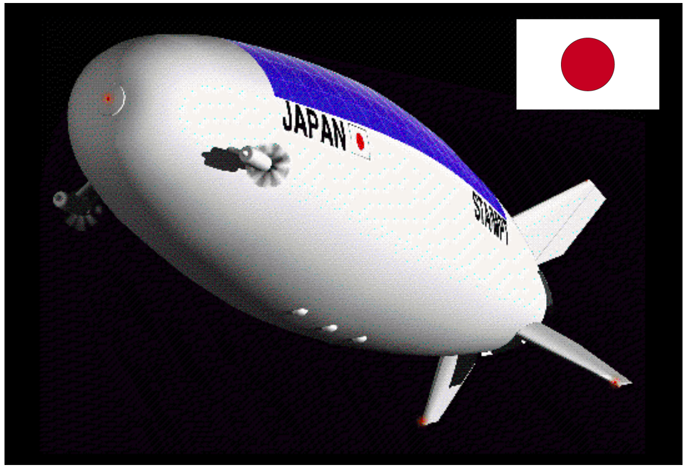
	Terrestrial (e.g. FWA)	HAP	Satellite (e.g. Teledesic)
Station Coverage (diameter, typical)	< 1 km	Up to 200 km	> 500 km
Cell Size (diameter)	0.1-1 km	1-10 km	50 km
Total Service Area	Spot Service	National / Regional	Global
Max Tx Rate	30 Mbits/s?	25-155 Mbits/s	< 2 Mbits/s
Mobility	Fixed	Vehicular → Fixed	Vehicular → Fixed
System Deployment	Several BS before use	Flexible	Many satellites before use
Cost of Infrastructure	?	$50 million → $1 billion ??	$9 billion ?
In Service Date	2001 ?	2002-2005 ?	2002 ?

5/ Some current and proposed programmes

AIRSHIPS

SkyNet

- For communications & monitoring applications
- Yokosuka Communications Research Lab
- Integrated network of some 10 airships planned to cover Japan



Sky Station

- 150 m class airship.
- Communications Payload 800 kg
- With Advanced Technologies, UK

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Some existing platforms: AIRPLANES

HALO (Proteus 9)

- Manned aircraft!
- For comms services
- Angel Technologies

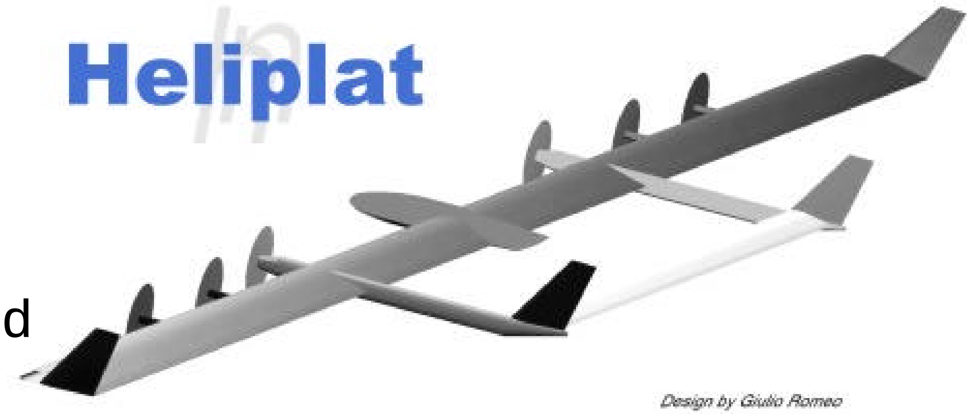
Military UAVs

Global Hawk

Predator

The HeliNet Project

- EU 5th Framework Grant
- Consortium led by Politecnico di Torino
- Based upon solar powered airplane
- Wing span up to 70 m
- Communications aspects led by University of York
- Also for localisation and remote sensing
- 3 year programme initially



HeliNet Consortium

Italy	Politecnico di Torino Carlo Gavazzi Space
UK	University of York Enigmatech Barclay Associates
Slovenia	Jozef Stefan Institute
Hungary	Technical University of Budapest
Spain	CASA Technical University of Catalonia
Switzerland	Ecole Polytecnique Federale de Lausanne Fastcom

Aim is to establish European industry on the competitive world stage in HAPs.

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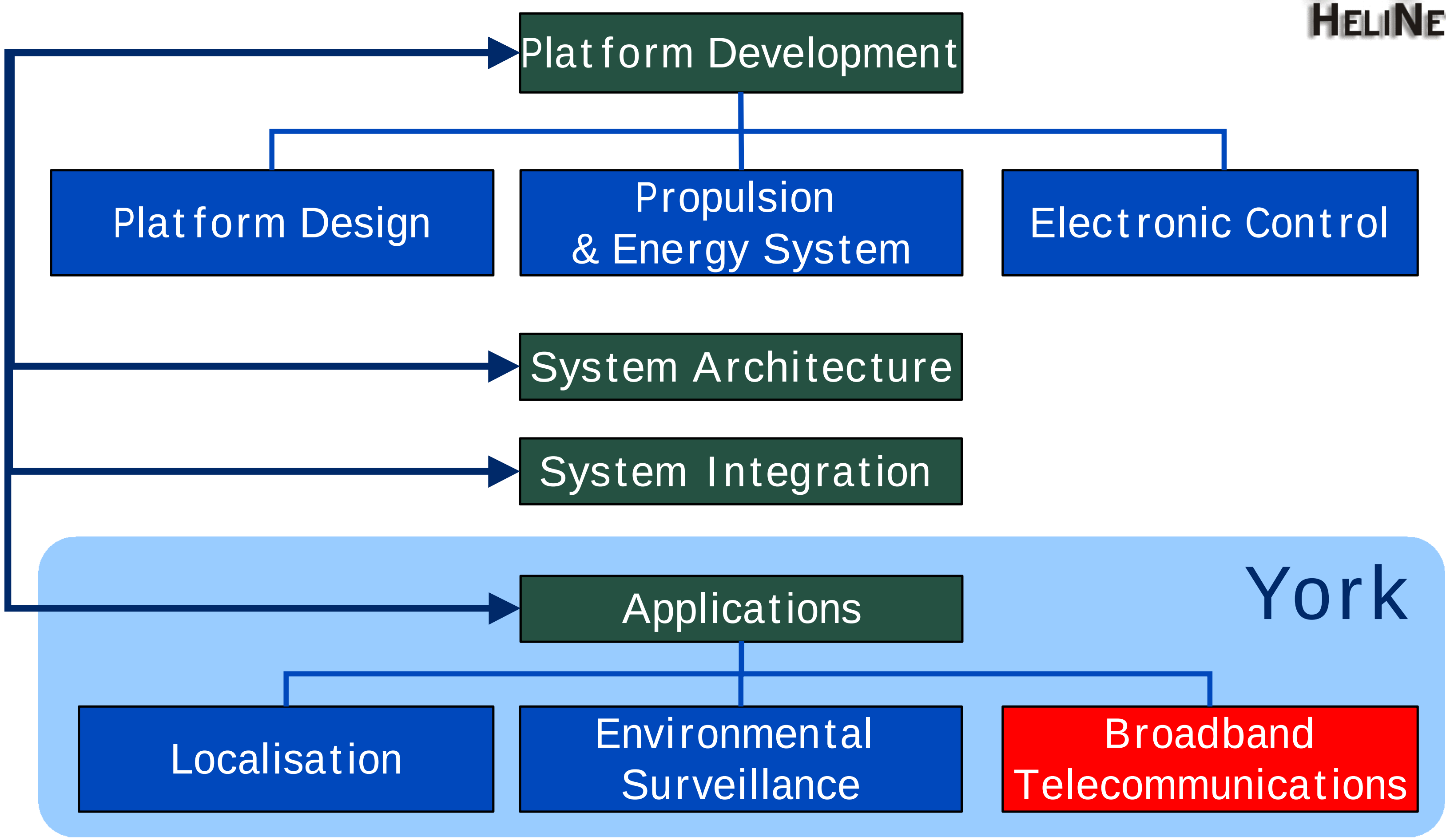
HeliNet Programme

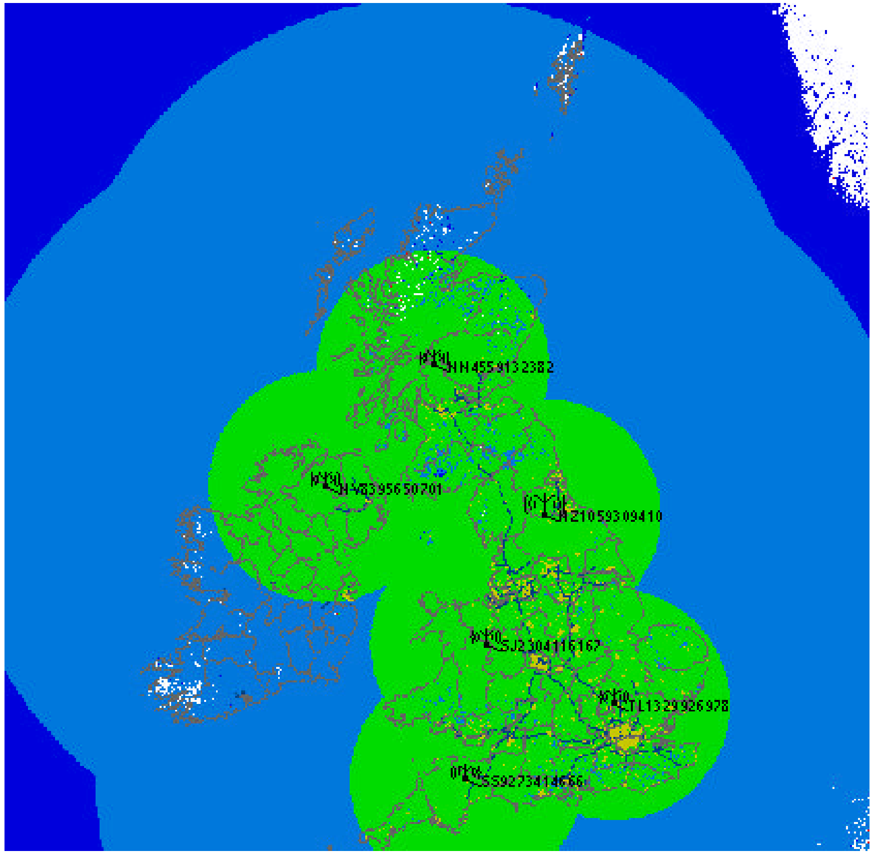


6/ HAP Communications Design Issues

(- with particular reference to BWA)

Need to plan:

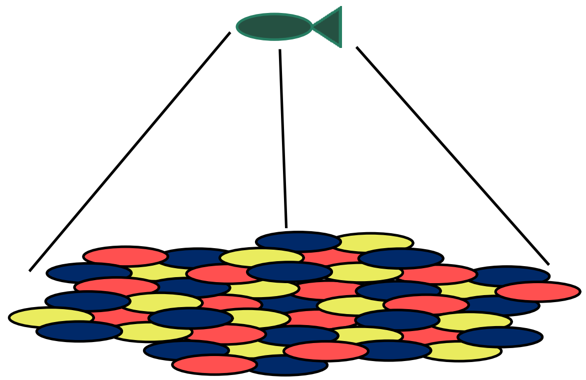
- Network Topology
  - HAPS can be **processing**, or **transparent**
  - Inter-HAP links very feasible
  - Backhaul may be challenging
- Air interface and protocols
  - IEEE 802.16 a basis?
  - Also DVB and other satellite formats

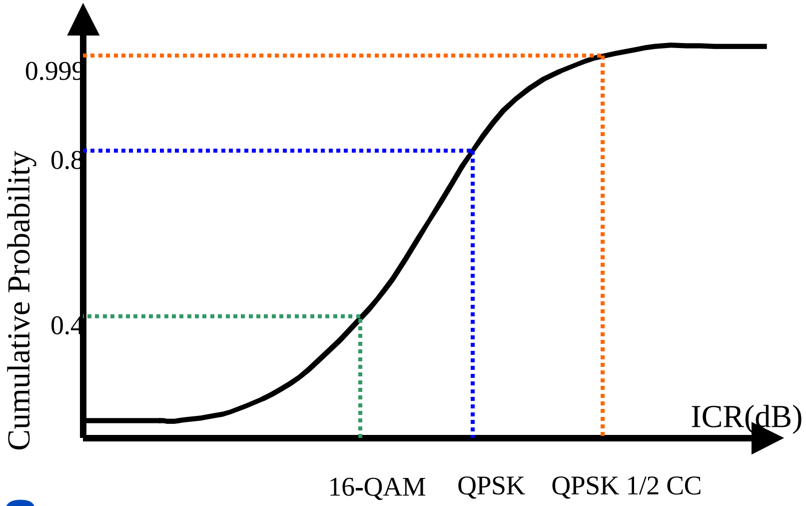


Network of HAPs over UK @ 20 km

Flexibility from HAPs

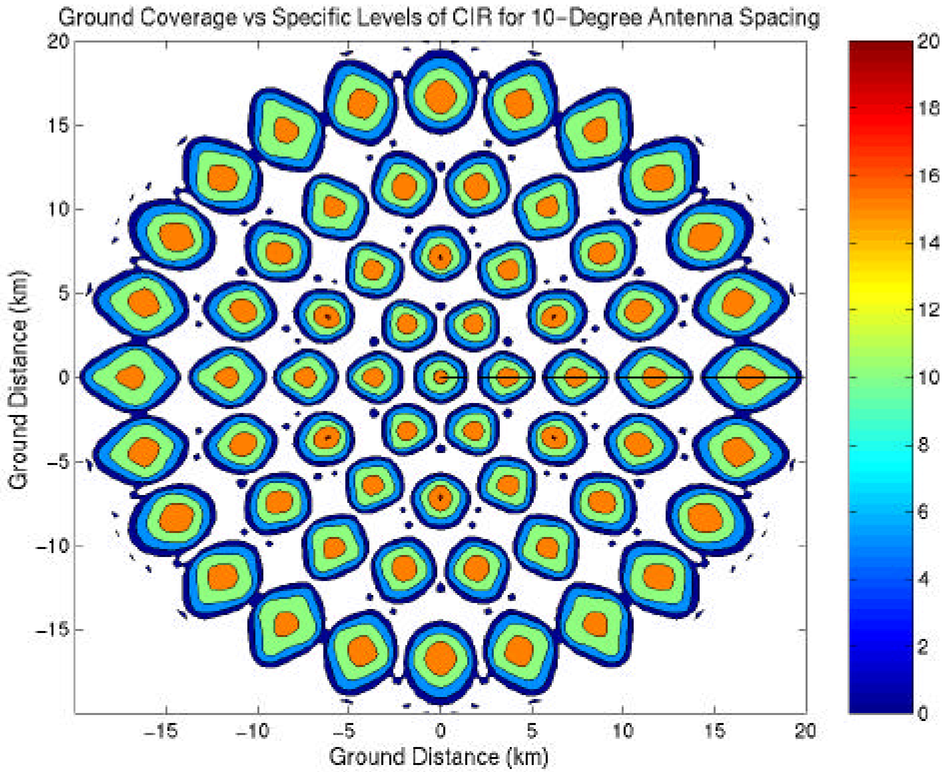
- Can exploit flexible **Dynamic Resource Allocation**
- Place beams where they are needed
- Adapt beam size and capacity
  - E.g.: During the day, capacity in city centres,
  - At night, over the suburbs
  - And in real time in response to traffic
- Use **Adaptive Modulation & Coding**
  - - esp. with rain fades etc
- All needed to maximise **CAPACITY** and hence **REVENUES**





Cellular Frequency re-use from HAPs

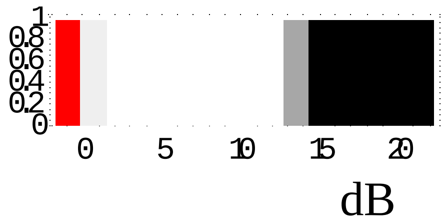
- New cellular patterns appropriate



- Antenna radiation patterns on HAP determine interference pattern on ground, and hence frequency re-use distance
- Function of
  - Antenna beam shape
  - Antenna angular spacing
  - Antenna sidelobe level
- Calls for sophisticated antenna technology on the HAP
  - Considerable challenge, esp. @ 48 GHz!

Example results: 4 frequency plan (48 GHz)

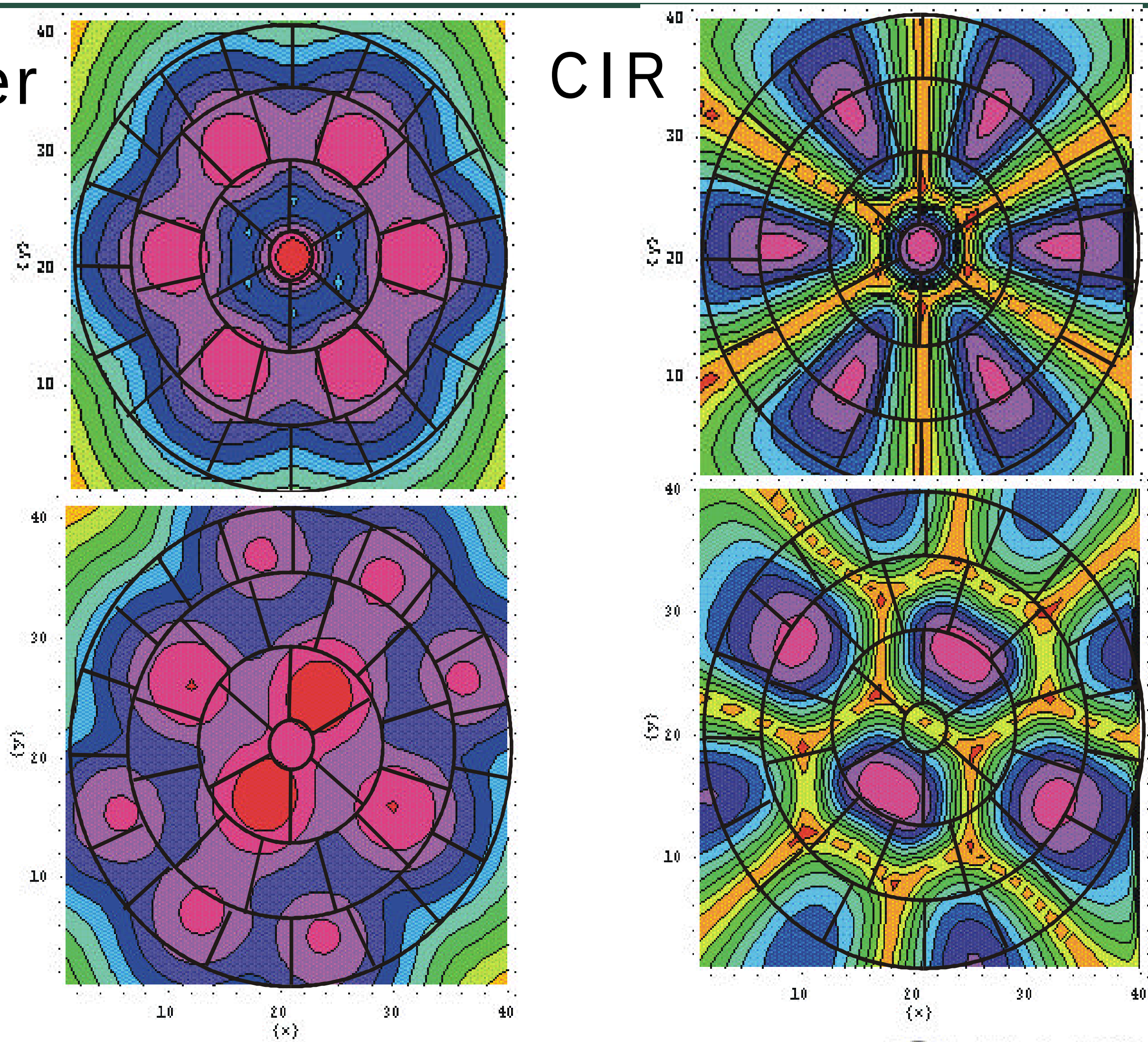
Frequency 2



Frequency 1, 3 or 4 (rotated)

Power

CIR



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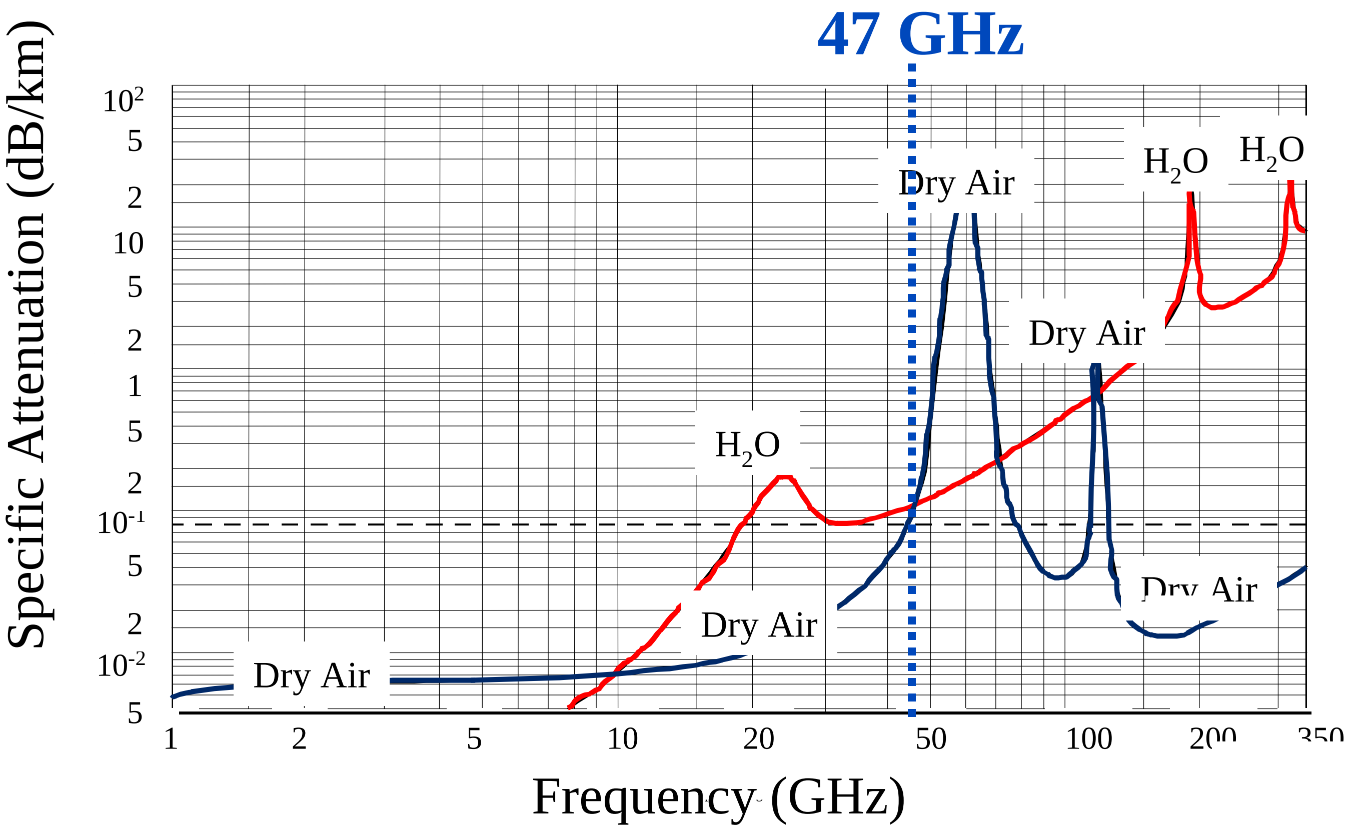
Propagation for BWA @ *mm* bands:

Atmospheric Attenuation an Issue



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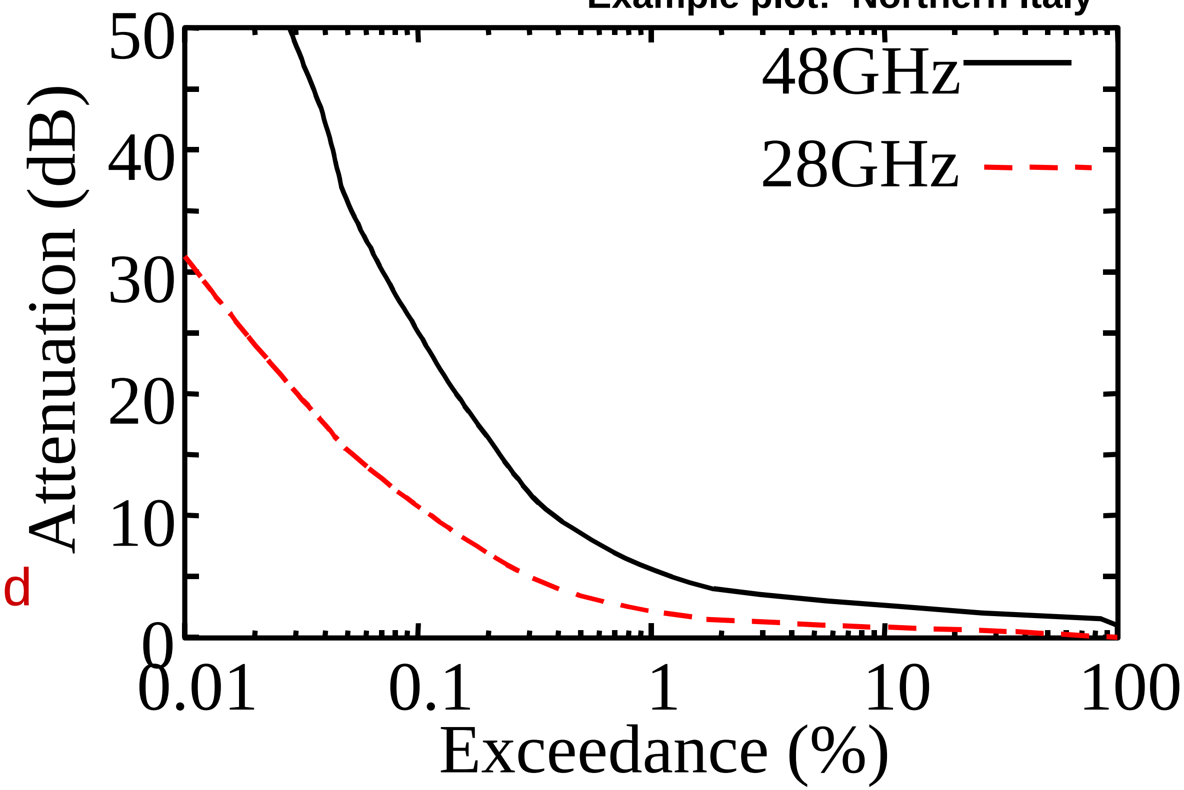
Propagation for BWA (contd.):

Also rain & cloud losses

- imply significant link margin, depending on Grade of Service (GOS) required

- May demand unrealistic margin
- Lesser penalty may be to accept modest GOS?
- Or redefine GOS?
- Similar problem to satellites @ Ka band
- Worse in tropical regions

Example plot: Northern Italy



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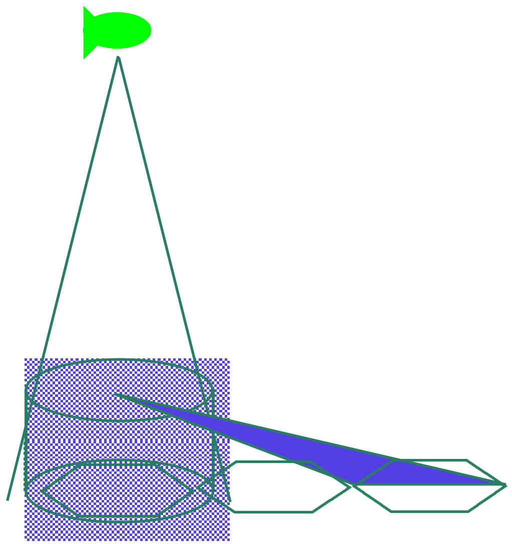
Scatter From Rain

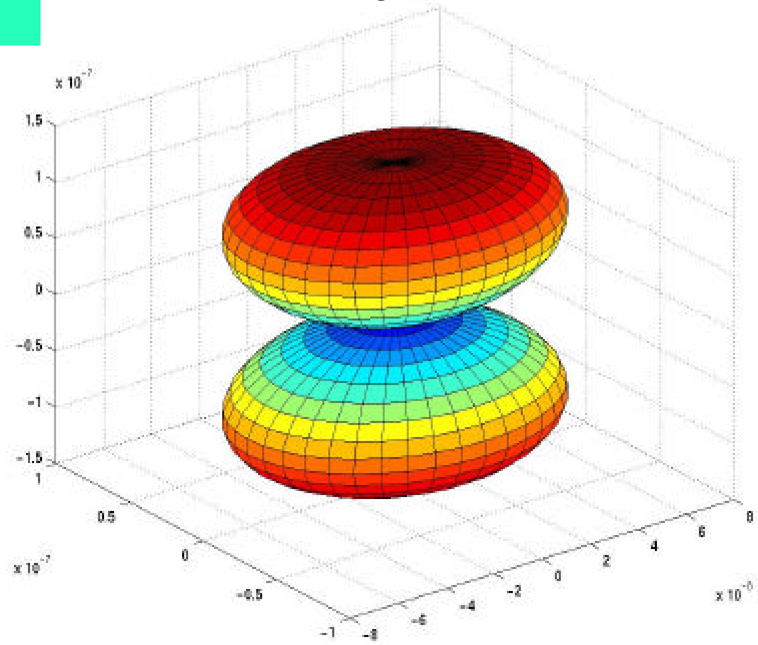
- Significant source of interference into co-channel cells
- Many small cells make problem worse than with satellite systems



Scattering Cross-Section of Raindrops

◆ Represents scattered power as fn. of direction, for vertically incident ray.

◆ Scattered power significantly greater at smaller wavelengths.



7/ Critical Issues and Challenges

Communications from HAPs:

- Antennas
  - Need to be steerable
    - To compensate for platform position and orientation
    - To produce large array of spot beams
  - Need to place spot beams where they are needed
    - Ideally adaptive to user location and traffic demands
  - Potential for phased arrays
  - The most demanding communications technology issue
- Propagation environment at *mm*-wavebands

Issues for HAPs (Platforms)

- Airship Structures and Dynamics
  - Aerodynamics critical
  - Cannot simply scale from small prototypes
  - Behaviour of large semi-rigid structures
  - Thermodynamic behaviour of large gas volumes

- Station Keeping
  - Will determine Grade of Service
  - Operations constrained to certain regions
- Stability
  - Attitude etc: antennas need to be stabilised
  - Easier for large airships
- Materials
  - New envelope materials

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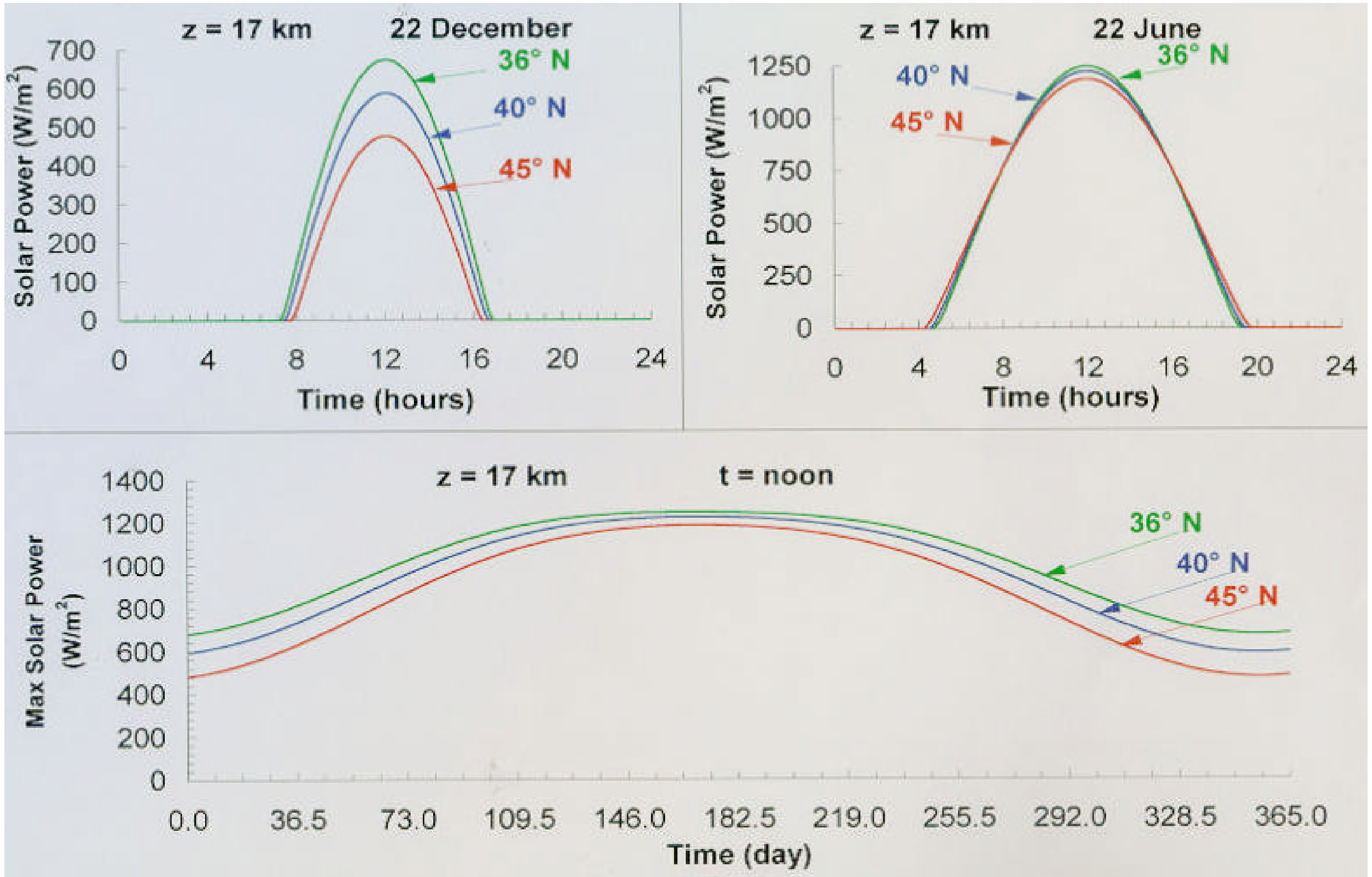
Issues for HAPs (Airships): Power

- Fuel Cells critical element
  - Will also determine replenishment time
- Problems in extreme latitudes

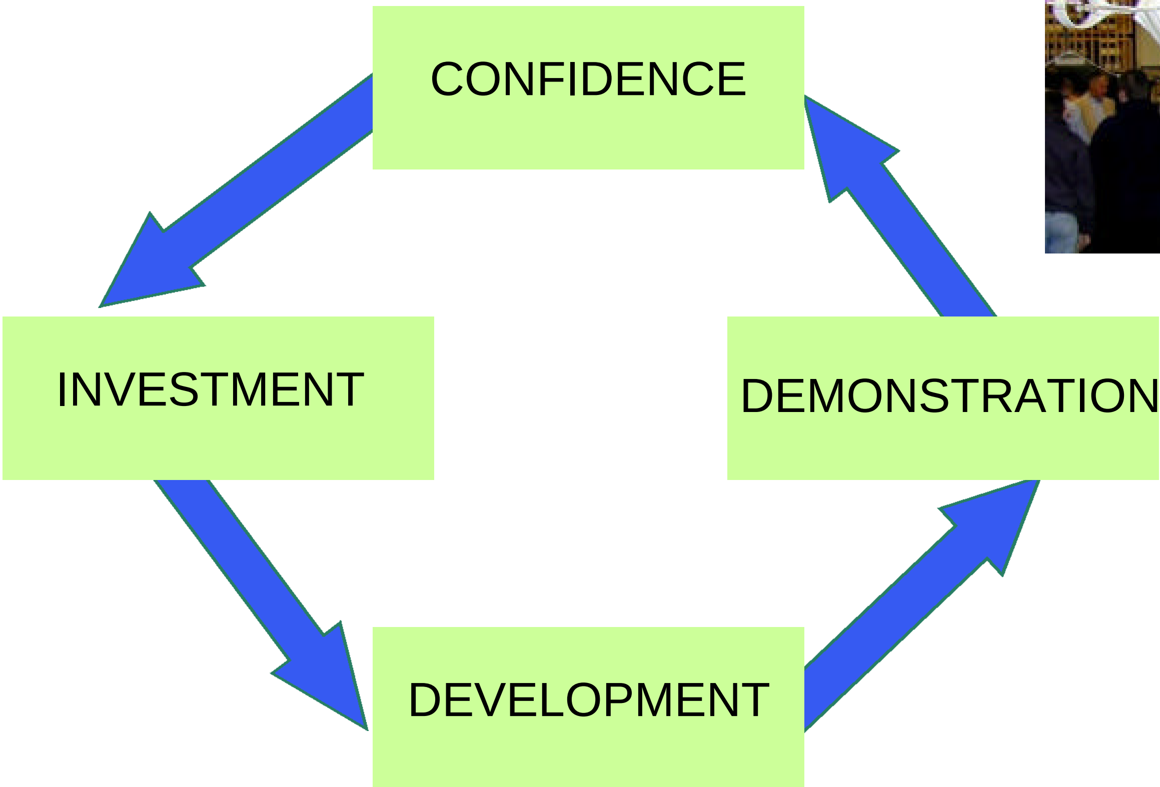


Acknowledgement to Polito

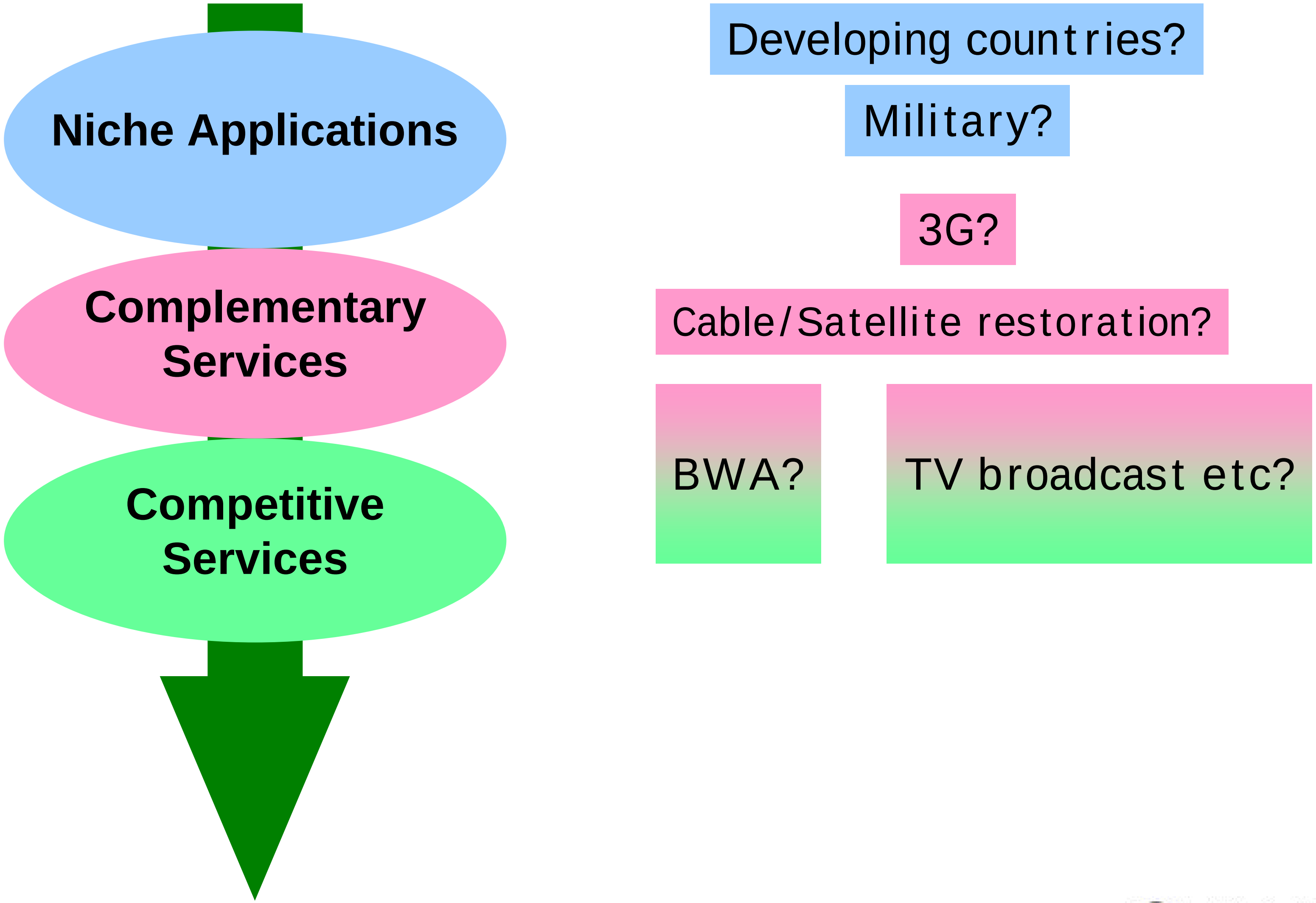
Issues for HAPs - general

- Getting them up and down
- Safety
- Regulatory
  - Aeronautical
  - Radio
- Investor and consumer confidence
  - Most HAPs still on drawing board
  - NIH - ‘Not Invented Here’
  - ‘Is it a plane, is it a spacecraft?’
- Cost
  - But need to consider overall cost of operation (‘Through Life Cost’)

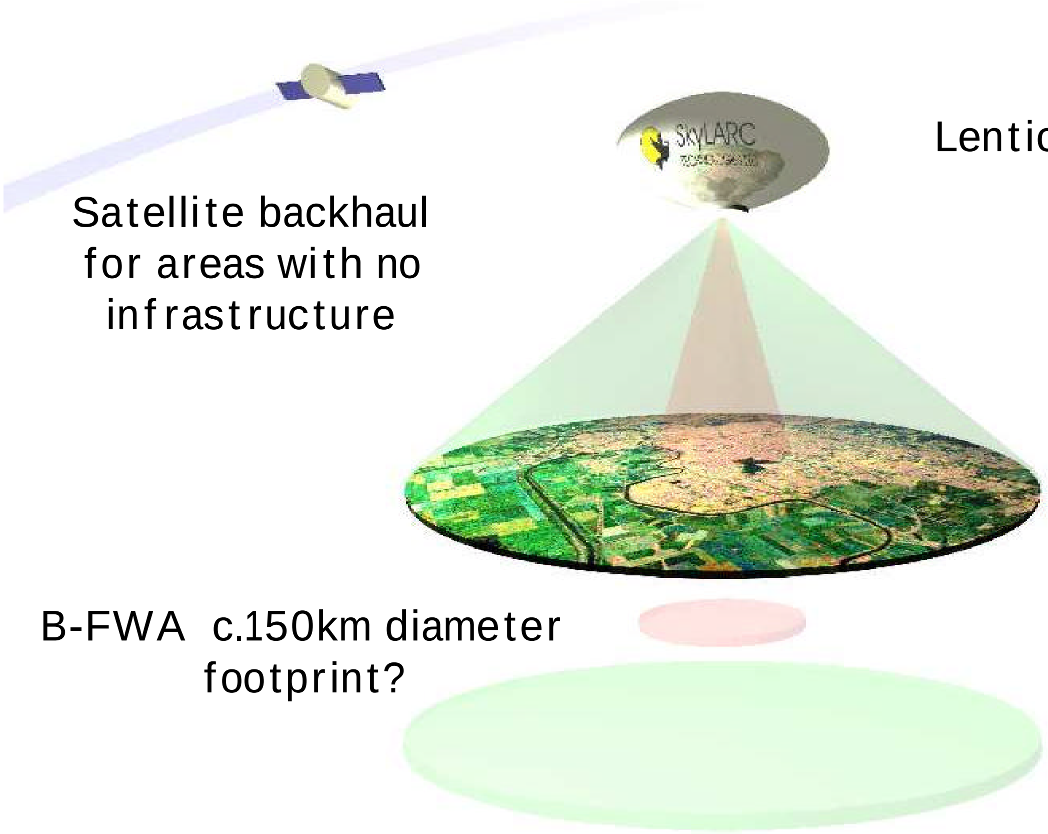
So, will HAPs really <u>Happen</u>?



Evolution of HAPs Services?



CONCLUSION: The Sky's the Limit!



8/ Acknowledgements and Contact

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SkyLARC TECHNOLOGIES LTD.

tct@ohm.york.ac.uk

www.amp.york.ac.uk/external/comms