行動測繪技術回顧與發展

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大綱

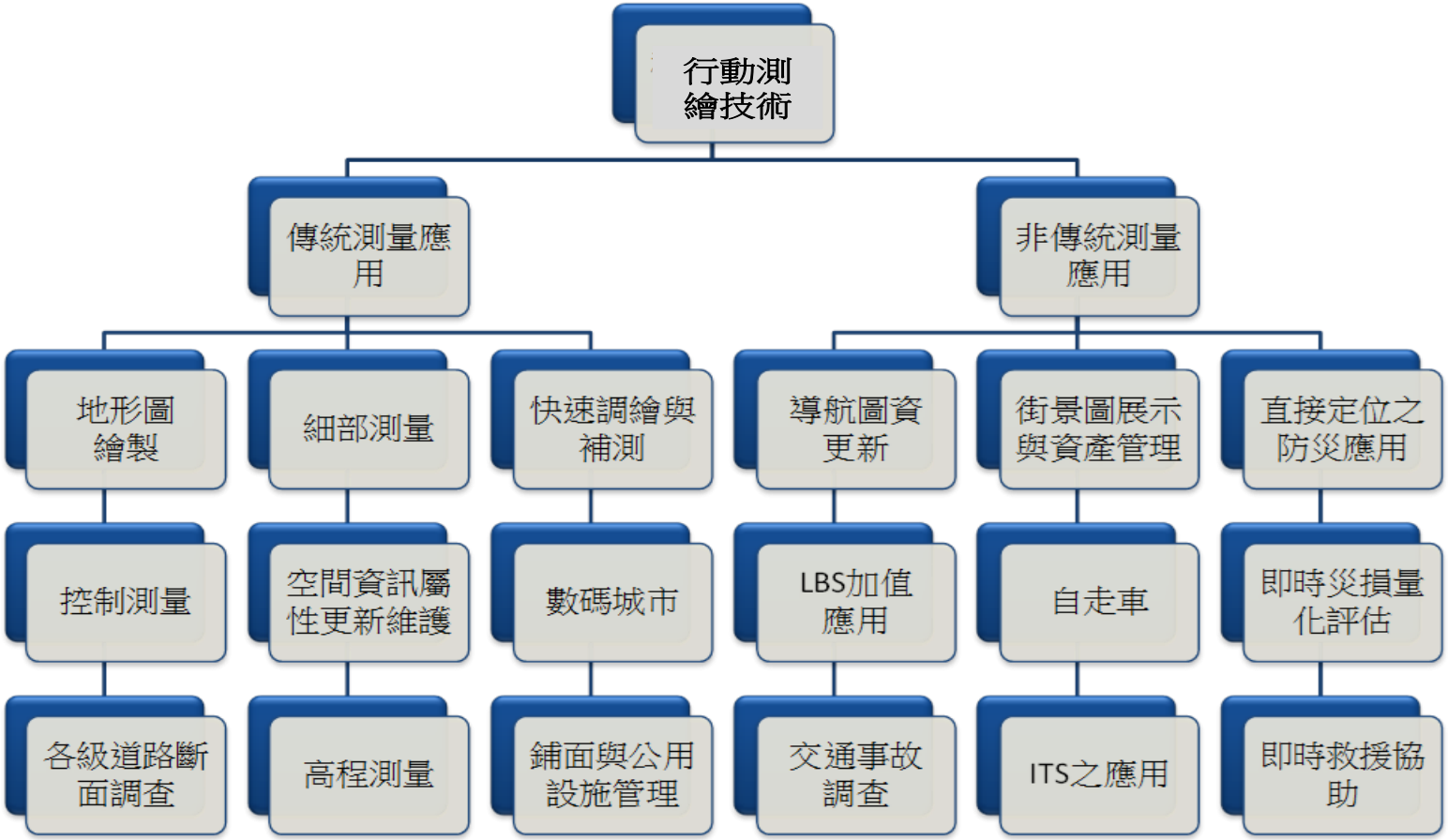
- 背景說明
- 車載系統
- 空載系統
- 船載系統
- 個人攜行系統
- 室內製圖系統
- 展望

背景說明

- 現有空間資訊系統之效益建構在系統空間及屬性資料時效性以及正確性，傳統測量以及屬性調查作業作業耗時，已不符合科技發展的趨勢與成本效益
- 攝影測量製圖的技術與精密複合式定位定向系統結合，搭配多種的數位影像感測器來收集空間資料，逐步實現快速即時行動測量及空間資料之多平台製圖技術
- 這類系統最早完全由空間資訊領域之學者為了空間資訊領域需求主導開發而設計的軟硬體架構，目前已廣泛應用於非傳統測量之應用領域中
- 使用多平台製圖技術建置空間資料，可更快速及有效規劃國土發展，進而推動空間資訊產業之成長。全球多平台製圖系統相關之空間資訊與非空間資訊產業應用未來還將持續成長

背景說明

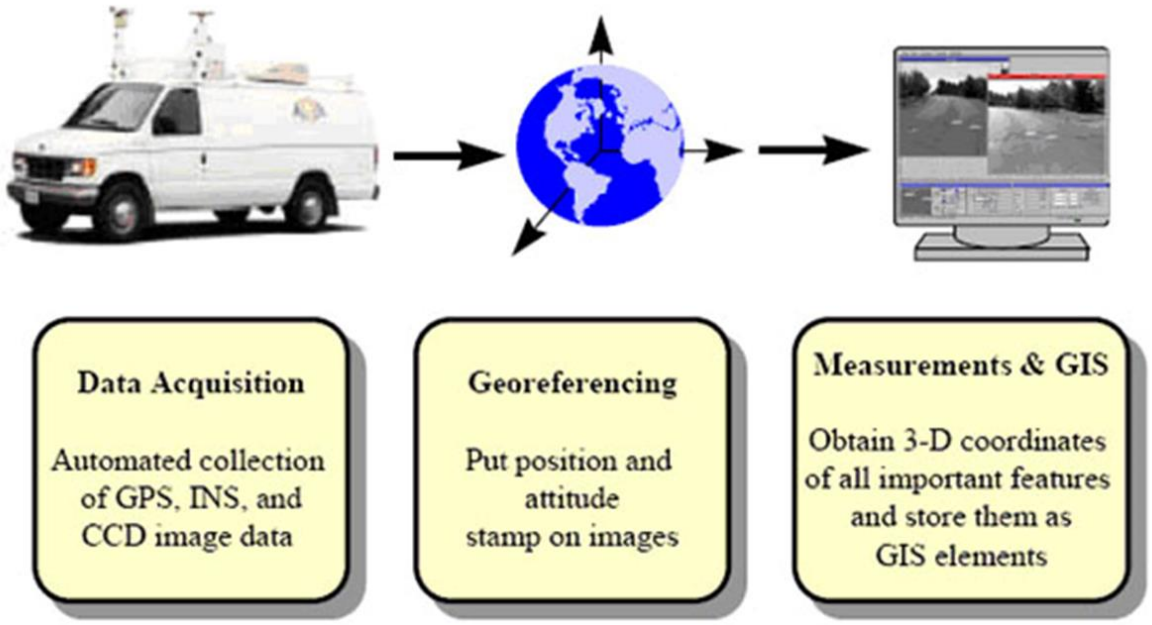
- 行動測繪系統之應用

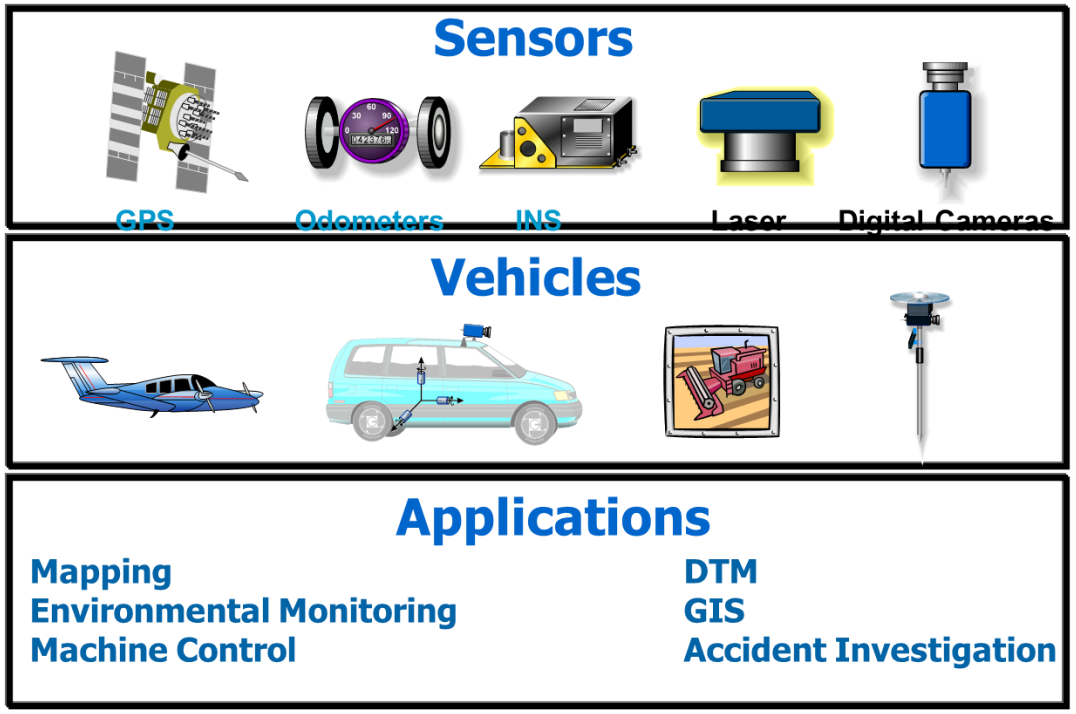


(摘自江凱偉等人，2014)

背景說明

- 行動測繪系統之作業流程與組成元件

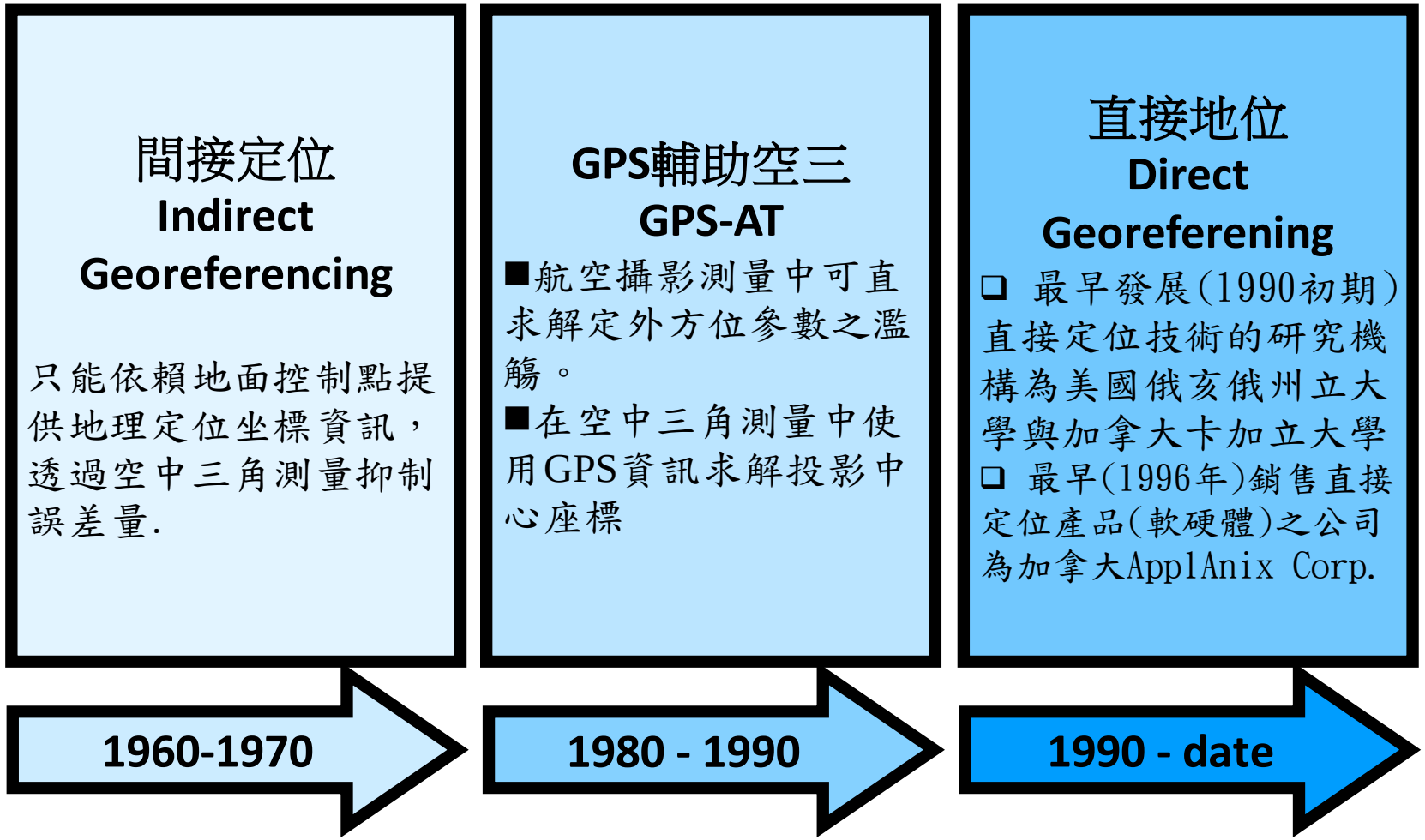




(El-Sheimy, 1996)

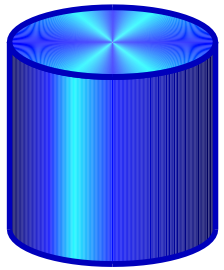
背景說明

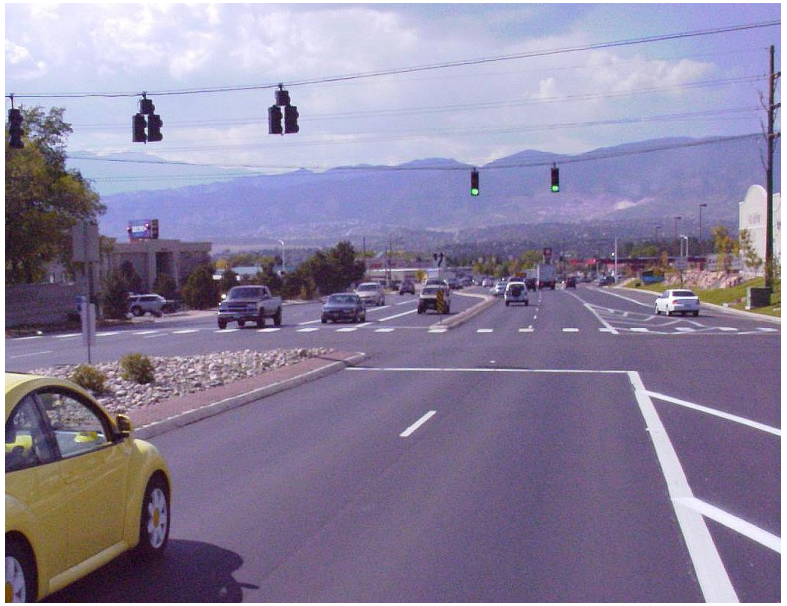
- 直接地理定位技術之演進



背景說明

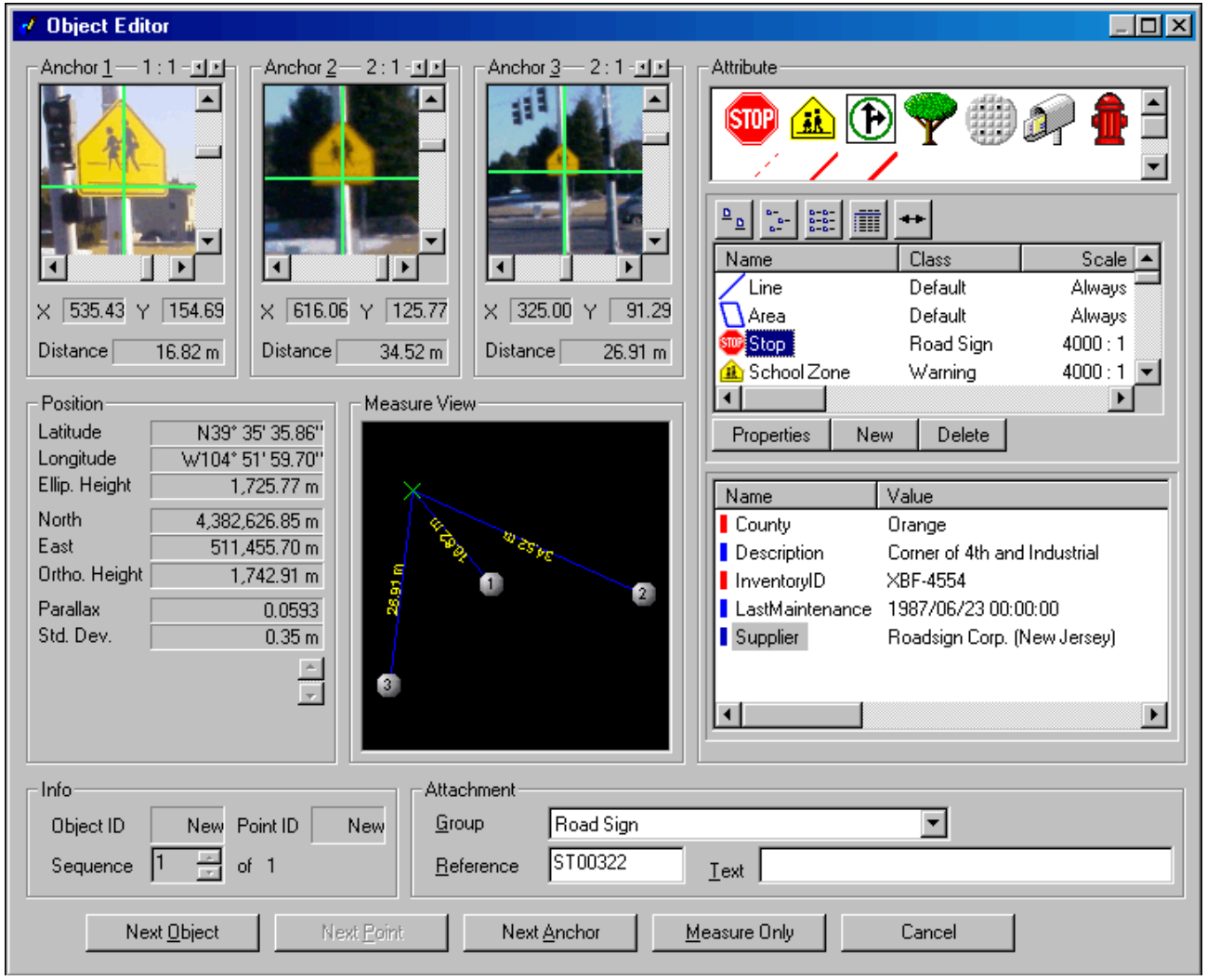
- 直接地理定位技術之概念



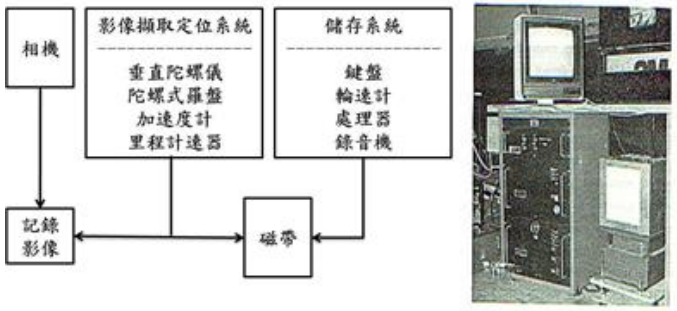


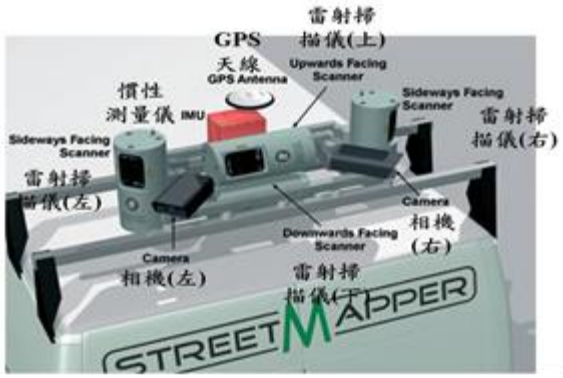
背景說明

- 直接地理定位技術之概念

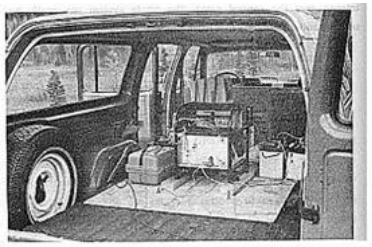


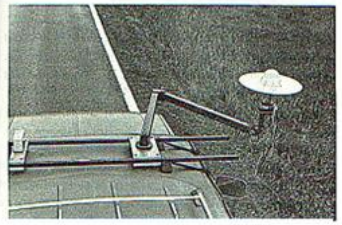
車載系統





(Street Mapper提供)





Alberta MHIS(摘自Lapucha, 1990)

TOPCON公司開發的移動測圖系統(摘自 http://www.topconpositioning.com/products/mobile-mapping/ip-s2)

車載系統

Google的行動測繪系統

http://www.google.com/maps/about/behind-the-scenes/streetview/)

立得空間測量車LD-2000 RH
(摘自Li et al., 2001)

Apple的行動測繪系統
(摘自http://appleinsider.com/)

Lynx Mobile Mapper(摘自
http://www.optech.ca/index.htm)

Here的行動測繪系統
(摘自https://www.here.com/)

車載系統

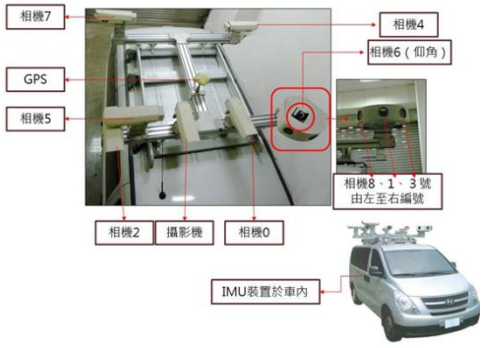
項目	規格說明
掃瞄系統	加拿大 Optech Lynx M1
掃瞄器(每秒點數)	2組(各500KHz)
最大掃瞄距離	200m (20%目標反射率)
旋轉鏡速度	80Hz~200Hz
測距精度 絕對精度	8mm (1 sigma) ±5cm (1 sigma)
眼安全性能	Class 1
工業級相機	4組(各500萬畫素)
車行速度	可達100km/hr

中興測量

自強

詮華

SGS



日昇

車載系統

群立科技

勤崴科技

經緯航太

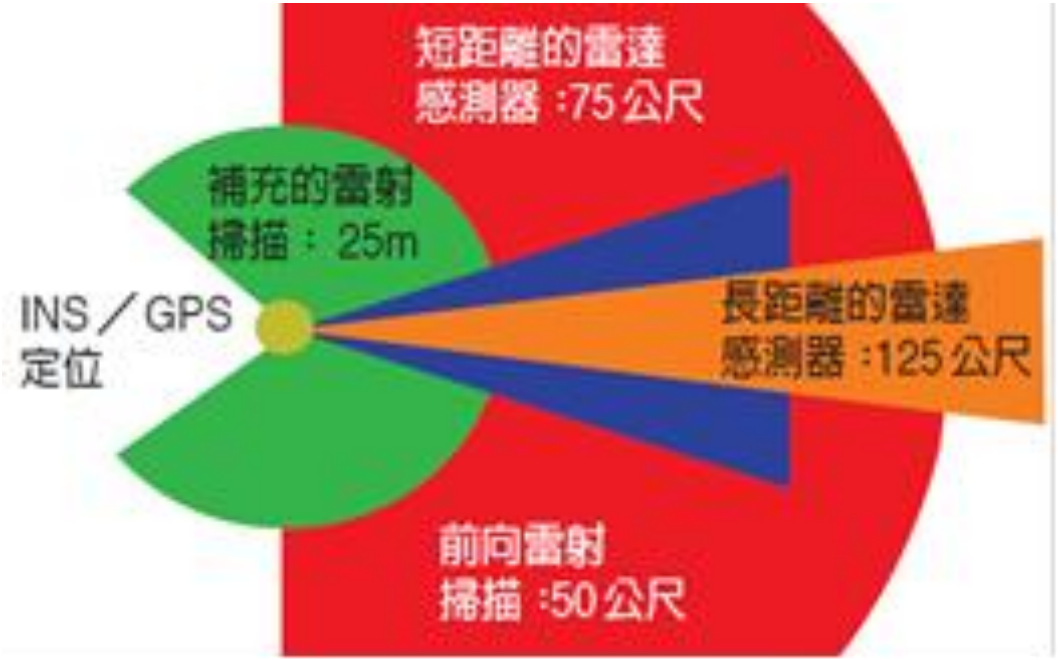
台灣國際航電

車載系統

國土測繪中心

車載系統

- 自走車與行動測繪技術



空載系統

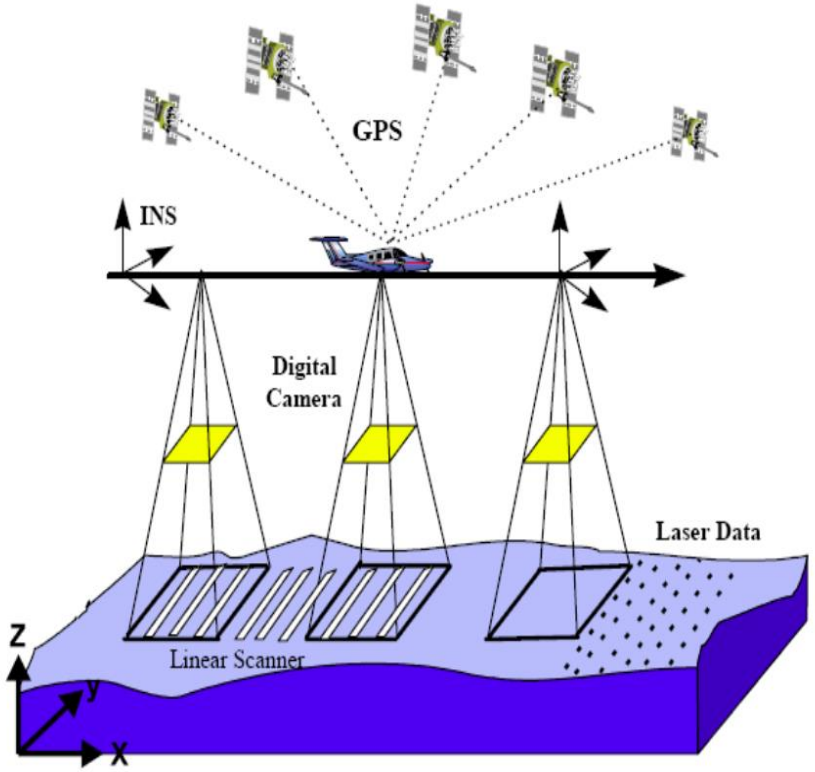
- 空載行動測繪技術的發展可追溯自1990年代初期，其中重要的里程碑可分為三個階段
  - 第一階段為前INS時期，約自1985年至1995年；
    - 在前INS時期，歐美諸多學者提出以GPS多天線陣列之方式提供飛機的姿態(Cohen and Parkinson, 1992；El-Mowafy and Schwarz, 1994)，如此可應用至空中三角之解算程序中
    - 此種設計所提供之精度(0.1至0.03度)受限於應用在航測飛機上可安置多天線陣列之基線長度(2至10公尺)與GPS整數週波未定值之解算問題
    - 無法成為具備直接定位能力的空載技術主流產品(Mostafa and Schwarz, 1999)。
  - 第二階段為後INS時期，約自1995年起至2000年；而最早配置慣性測量儀之研究型空載行動測繪技術，為由加拿大卡加利大學空間資訊工程系所開發(Skaloud et al, 1996)。
  - 最後一個階段為空載光達時期，約自2000年起至迄今。

空載系統

- 空載系統

(摘自Skaloud et al, 1996)

(摘自Toth and Grejner-Brezezinska, 1998)



空載系統

- 商用空載行動測繪技術之範例

Full Frame Single Digital Camera

Applanix - Digital Sensor System (DSS)

3-line Pushbroom Scanner

Leica - Airborne Digital Sensor (ADS40)

Multiple Full Frame Digital Camera

ZI - Digital Mapping Camera (DMC)

空載系統

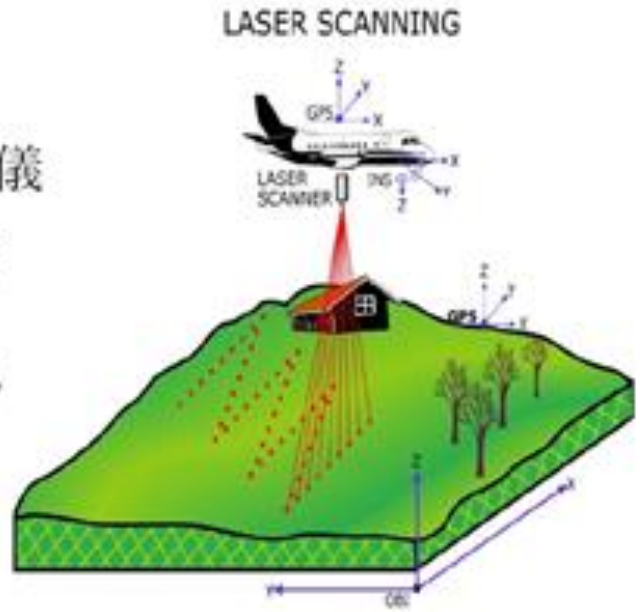
- 空載系統
  - 空載雷射掃描系統之範例

系統

1.位置: GNSS

2.姿態: 慣性測量儀

3.雷射掃瞄儀(波長500~1500nm), 爲高頻率掃瞄儀, 接收反射訊號, 量測訊號單行方向時間



The Leica ALS40

- 掃瞄視角可高達75度
- 振盪器旋轉角度精度高達0.001度
- 雷射脈衝頻率爲15~30KHz
- 使用相同一致的坐標系統

空載系統

- 無人機系統 (國土測繪中心, 2008-now)

空載系統

- 無人機系統 A Mini Helicopter was applied for MMS applications (Eisenbeiss, 2008)(Institute of Geodesy and Photogrammetry, ETH Zurich)

Mini UAV-system Copter 1b	
Length	2m
Rotor diameter	1.8m
Maximum takeoff weight	15kg
Payload capacity	5kg
Flight endurance	Max. 45min
Altitude	1500m
Range	5km

Parameter	Value
Image scale	1:4000
Side / end lap	75% / 75 %
Flying height above ground	~ 80 m
Camera	Canon EOS 20D
Focal length (calibrated)	20.665, RMSE 1.5e-003 mm
Pixel (Image format)	8.25 megapixels (3520x2344)
Flying velocity	3 m/s

Left: Derived surface model from image matching, Middle: Zoom-in of an UAV-image, Right: Point cloud of Helicopter-based LiDAR projected on the derived surface model.

空載系統

- 無人機系統 Multi-sensor integration for UAV mapping (Nagai, et al., 2008)(The University of Tokyo)

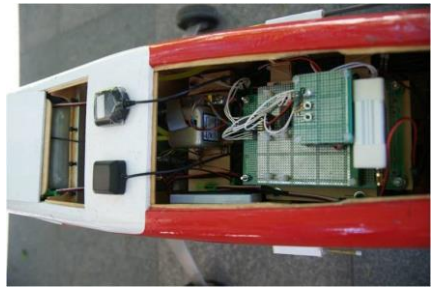
Sensors	Model	Specification
Digital Camera	Canon EOS 10D	3,072×2,048 pixels Focus length: 24.0mm Weight: 500g
Digital Camera	Canon EOS 5D	4,368×2,912 pixels Focus length: 15.0mm (Fish eye lens) Weight: 500g
IR Camera	Tetracam ADC3	2,048×1,536 pixels Green, Red and NIR sensitivity with bands approximately equal to TM2, TM3 and TM4. Focus length: 10.0mm Weight: 500g
Laser Scanner	SICK LMS-291	Angular resolution: 0.25° Max. Distance: 80m Accuracy (20m) : 10mm Weight: 4,000g
IMU	Tamagawa Seiki Co., Ltd TA7544	Fiber Optic Gyro Accuracy Angle: ±0.1° Angle Velocity: ±0.05°/s Acceleration: ±0.002G Weight: 1,000g
GPS	Ashtech G12	Accuracy Differential: 40cm Velocity Accuracy: 0.1(95%) Weight: 150g

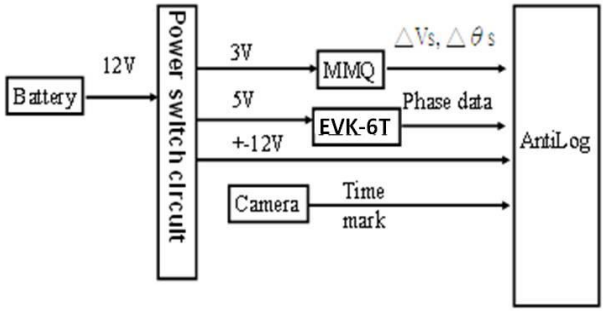
空載系統

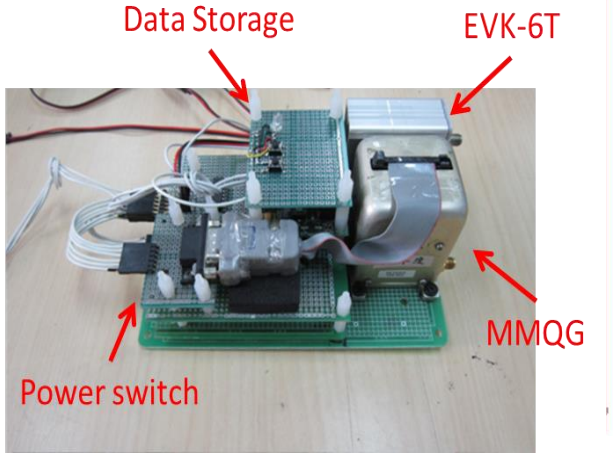
- 無人機系統 UAV Borne Direct Georeferenced Photogrammetric Platform for GCP free applications (Tsai, and Chu, 2012, ION GNSS 2012 Best Student Paper Award)(NCKU)

Wing span	5.0 m
Fuselage length	3.5 m
Endurance	> 6 hr
Range	500 km
Operation range	100 km
Payload	25 kg

Item		Specification
I/O interface		Servos: 5 、GPIO: 2 、Analog Input: 2
Communication		RS232 : 2 channels 、CAN BUS : 1 channel
Transform frequency		900 MHz ISM, 1W (typical – LOS 50km+)
GPS module		5 Hz 、5~10 m accuracy
Pressure sensor		-Ported Static. 15 - 115 KPa -Ported Pitot. 4KPa Deferential, 280 Km/h airspeed
Navigation and fly control in horizontal	Waypoint	1000+ waypoints navigation saved in autopilot
	Error range	Waypoint ± 20m
		± 3° Pitch and Roll
Fly control in vertical	Error range	±20m
		± 8 km/hr
Support		Digital Camera 、Speed Dome
Data record		Micro SD, 20Hz
Electrical system		Vin: 6.8~14 DCV Power: 450mA @ 7.4DCV; 850mA with 900MHz RF
Size		Size: 90 x 60 x 30 mm Weight: 220 grams with 900 MHz radio
Working environment		Operating Temperature: -40 to +85℃







空載系統

- 無人機系統 *A micro-UAV with the capability of direct georeferencing (Rehak, et al., 2013)(EPFL)*

+ Higher redundancy
+ Better orientation for the pilot
+ Compactness
+ More agile
+ Wider field of view for a camera
+ Better response to wind gusts
- Efficiency loss 15-30%
- Slightly worse stability

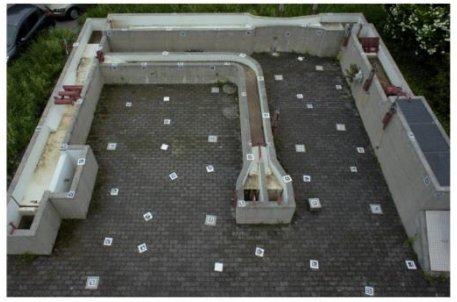
Main characteristic of a coaxial setup

Camera-lag statistics in a manual mode.

Number of samples	88
Max. delay	0.486 s
Min. delay	0.406 s
Mean	0.433 s
STD	0.013 s

Measured vs. estimated Lever Arm

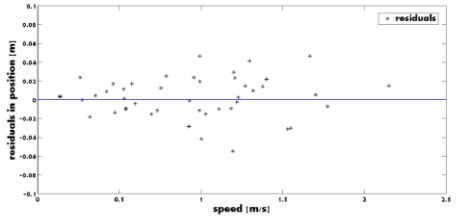
Lever Arm	Measured [cm]	Estimated by Bingo [cm]
Ex	5.5	5.6
Ey	1.0	0.1
Ez	19.5	19.4



Summary of integrated - sensor orientation (AT+GPS+1 GCP)

	X [m]	Y [m]	Z [m]	no.
Airborne GPS accuracy	0.016	0.016	0.037	46
Photo positions RMS (GPS-AT)	0.017	0.025	0.024	46
Control point	0.000	0.026	0.002	1
Check points RMS	0.036	0.022	0.019	6

Variations in measured and AT-estimated camera position.



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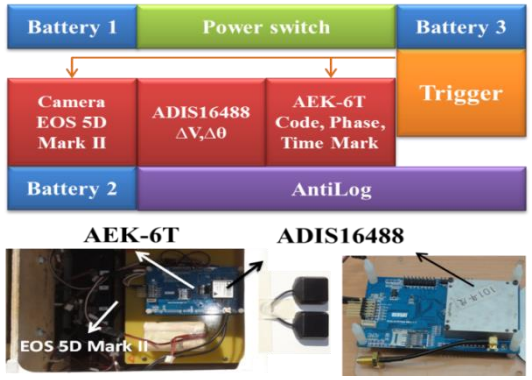
空載系統

- 無人機系統 UAV-Borne MMS Payloads(Chu, 2014, ION GNSS 2014 Best student paper award)(NCKU+ University of Calgary+ Purdue University)

Wing span	3.8 m
Fuselage length	3.3 m
height	0.8 m
Payload	40 kg
Endurance	> 8 hr
Range	800 km
Flight height	4000 m
Max speed	145 km/hr



ADIS16488

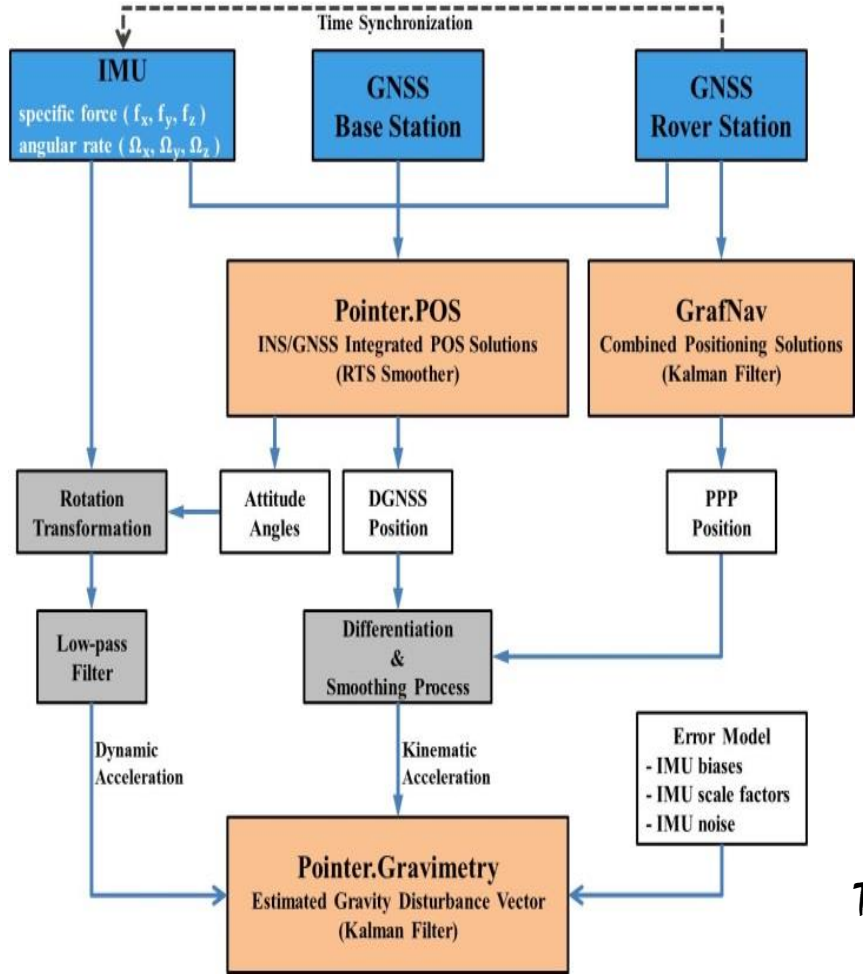
MMQG

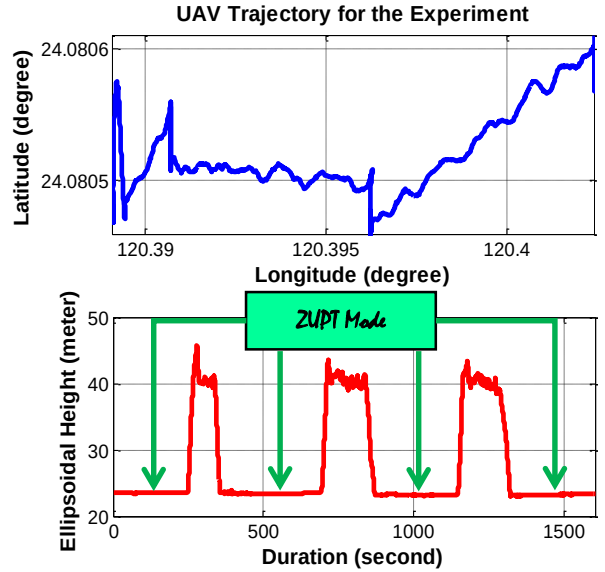
item	ADIS16488	MMQG	unit
GYROSCOPES			
range	±450	±200	°/sec
Misalignment	±0.1	±0.3	Degrees
Initial Bias Error (1σ)	0.2	0.03	°/sec
In-Run Bias Stability (1σ)	6.25	100	°/hr
Angular Random Walk (1σ)	0.3	0.3	$°/\sqrt{hr}$
ACCELEROMETERS			
range	±18	±10	g
Misalignment	±0.1	±0.3	Degrees
Initial Bias Error (1σ)	16	2.5	mg
In-Run Bias Stability (1σ)	0.1	3	mg
Velocity Random Walk (1σ)	2.9	0.5	$mg/\sqrt{hr}$

空載系統

- 無人機重力調查系統(Lin, 2016, ION GNSS 2016+ Best Student paper award)

Only Helicopter Weight	9 kg
Max. Take-off Weight	30 kg
Battery Weight	5~10 kg
Payload	15 kg
Max. Operational Range	40 km
Max. Cruise Speed	85 km/hr
Max. Endurance	1 hr
Power Voltage	45V~50V (12S Li-Po)



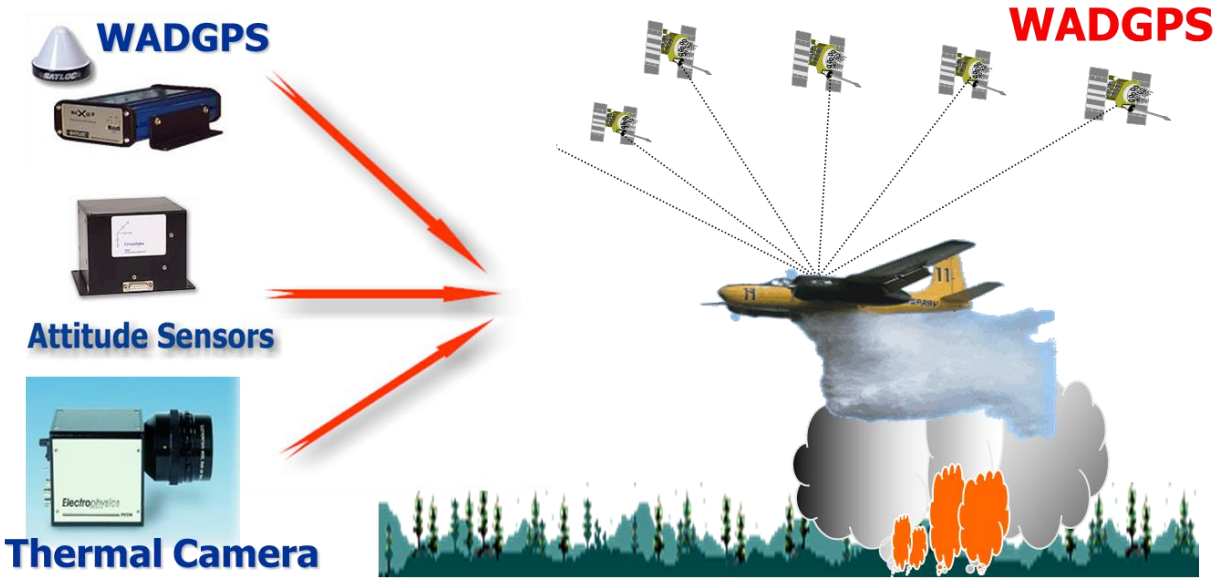


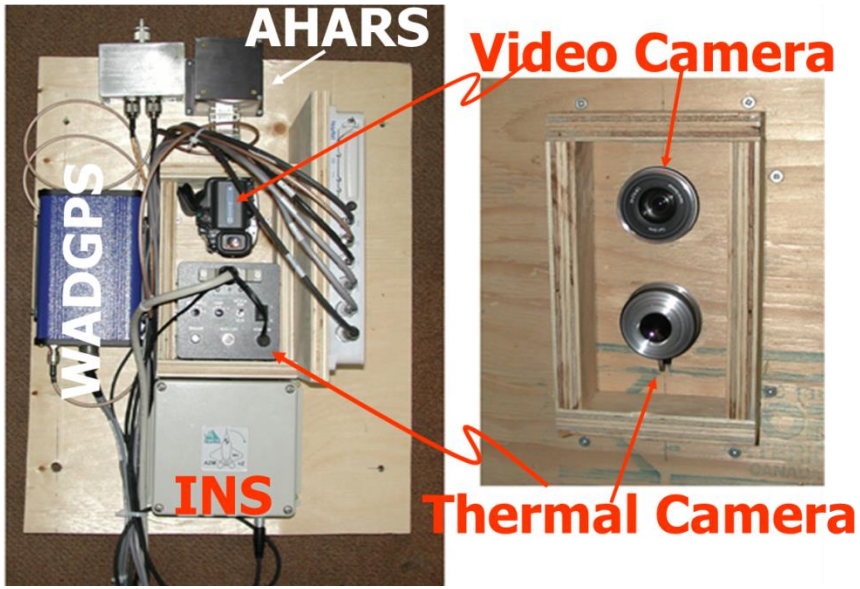
		INS/PPP-GNSS	INS/DGNSS
North	Mean	8.76	2.08
	STD	5.48	1.60
East	Mean	4.84	1.40
	STD	3.73	2.11
Down	Mean	5.45	3.16
	STD	0.81	2.08

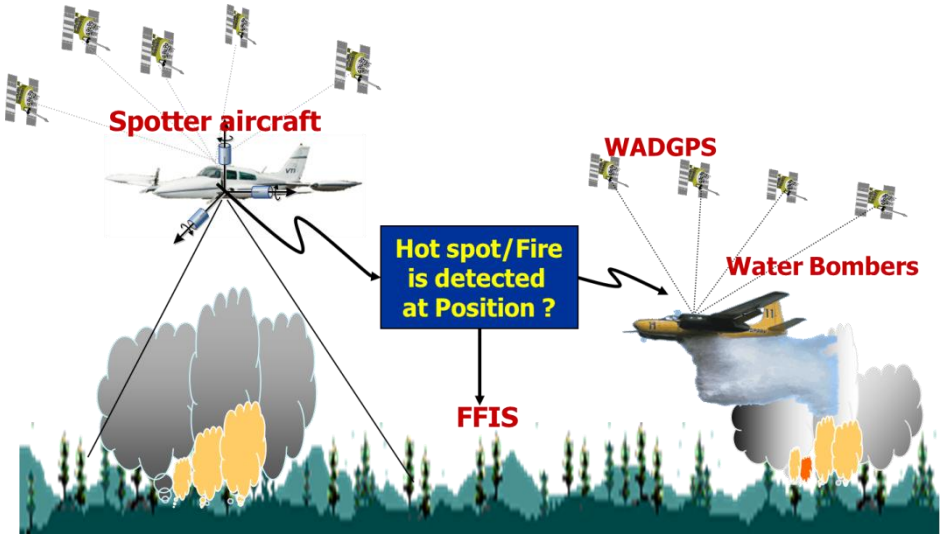
The statistics (mGal) of the differences between the repeat measurements

空載系統

- 即時森林火點偵測系統





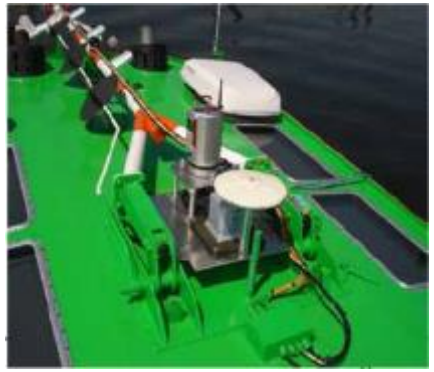


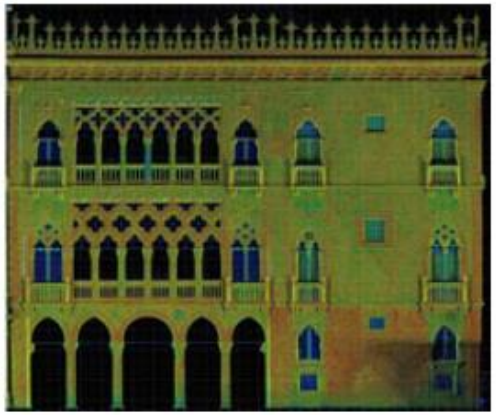
- Real-time reporting of the exact situation of fires
- Assisting the Forest Fire Information Centers in accurately assessing the fire
- Precisely directing water-bombers and fire-fighting crews

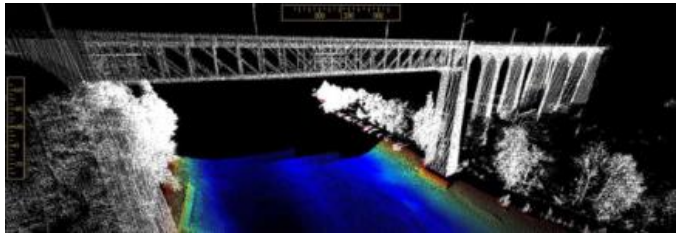
空載系統

船載移動製圖



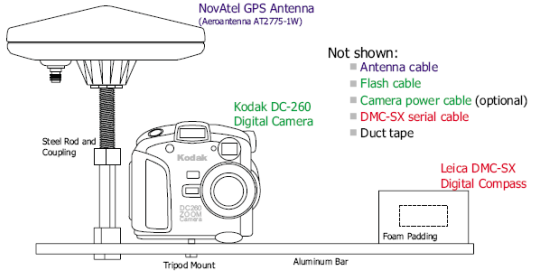







(摘自Zach et al.,2011)

個人攜行系統



(摘自 Ellum, 2001)

(https://www.google.com/streetview/understand/)

個人攜行系統

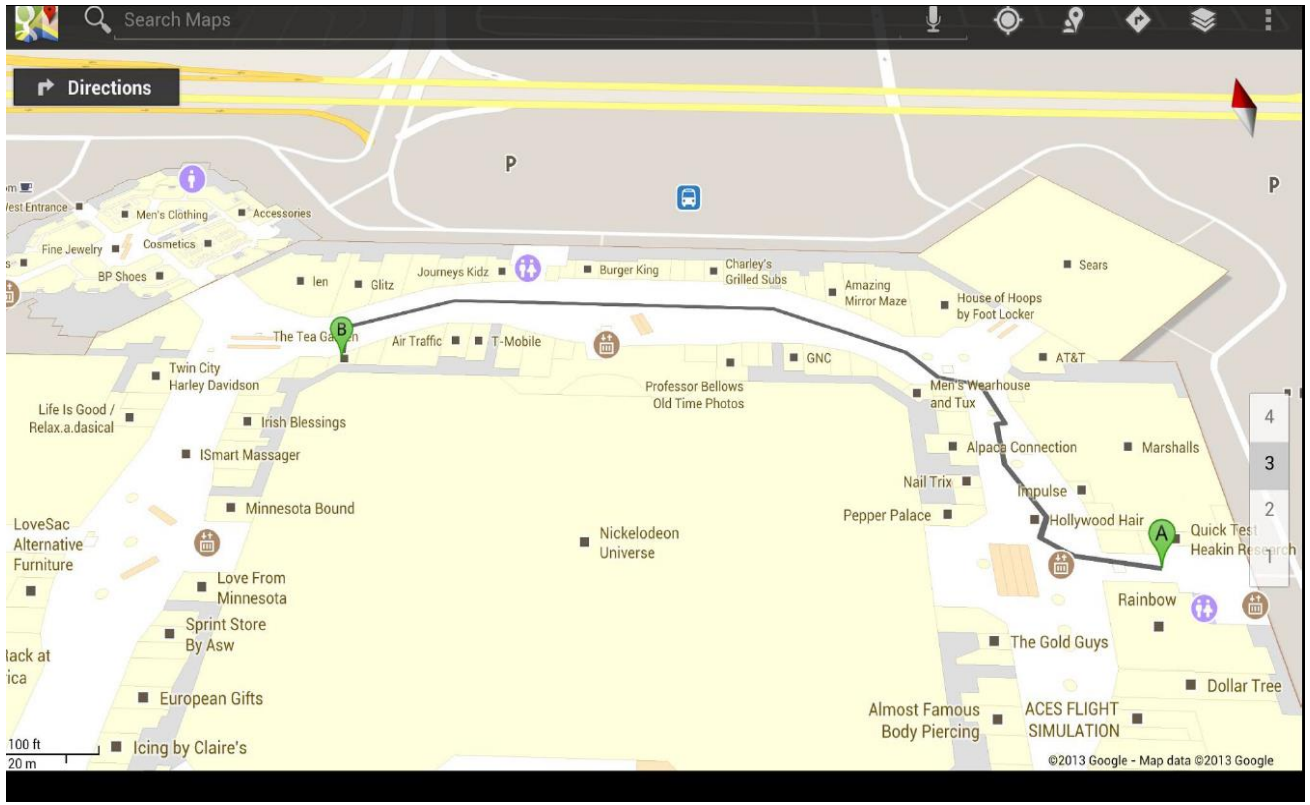
手機級室內製圖系統(摘自 https://www.google.com/atap/projecttango/

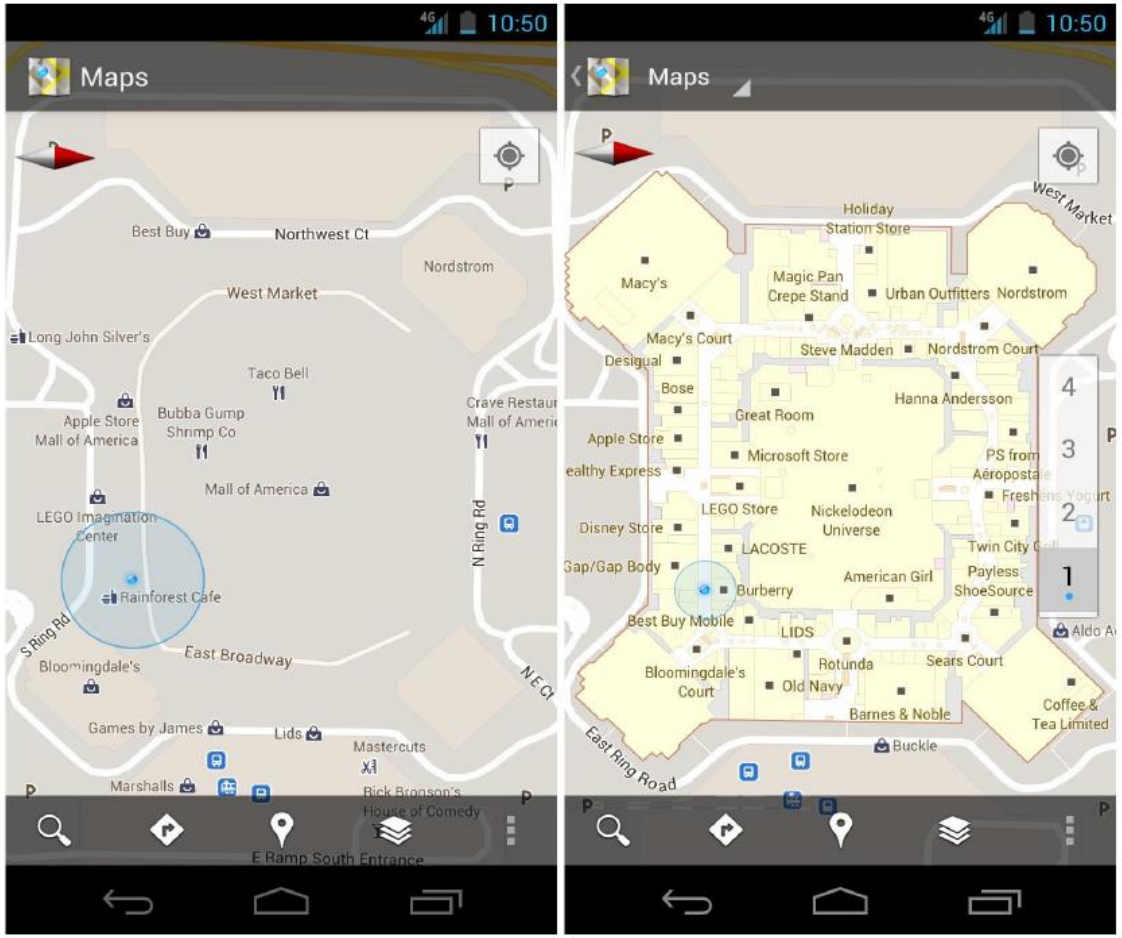
室內製圖系統

- 似曾相識的場景

室內製圖系統

- 為何需要室內平面圖?

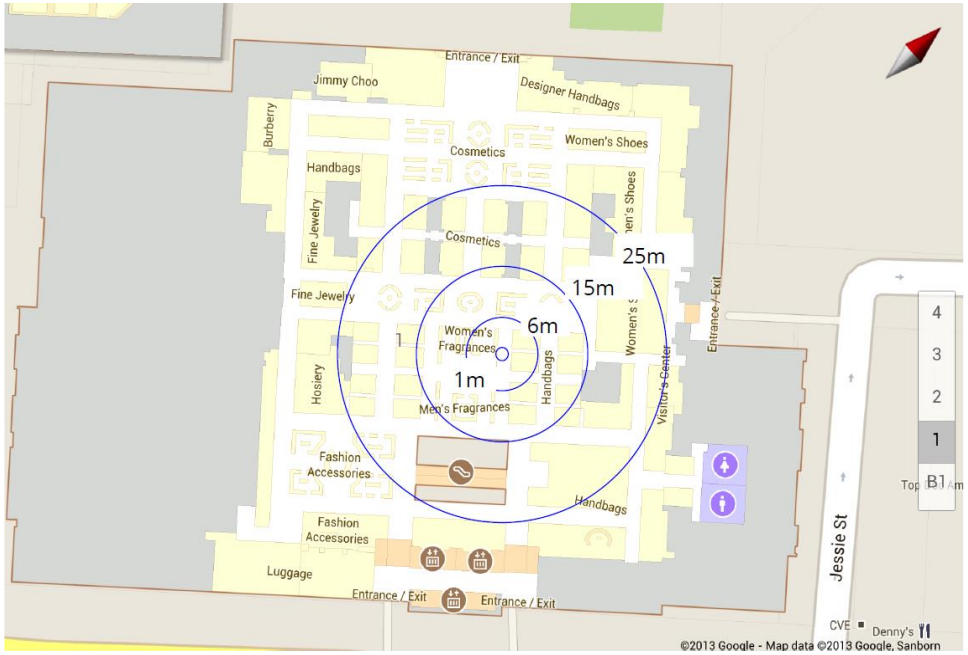




Courtesy of Google Inc.

室內製圖系統

- 室內圖資精度需求
  - Room level
  - Desk level



Courtesy of Google Inc.

Opportunities

Enterprise- Tracking Asset, Personnel, Security

Shopping Advertising

Assistant Social Gaming

Analytics…

Challenges

Eco-system:
Indoor maps & with context

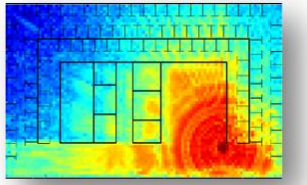
Venue & Floor Level

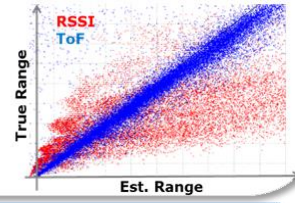
AP deployment

Physics:
Light 1ns error = 30cm
RF Indoor propagation

Methods:
ToF, TDOA, RSS, Sensors Fusion, Beaconing

Accuracy : ~5-10m

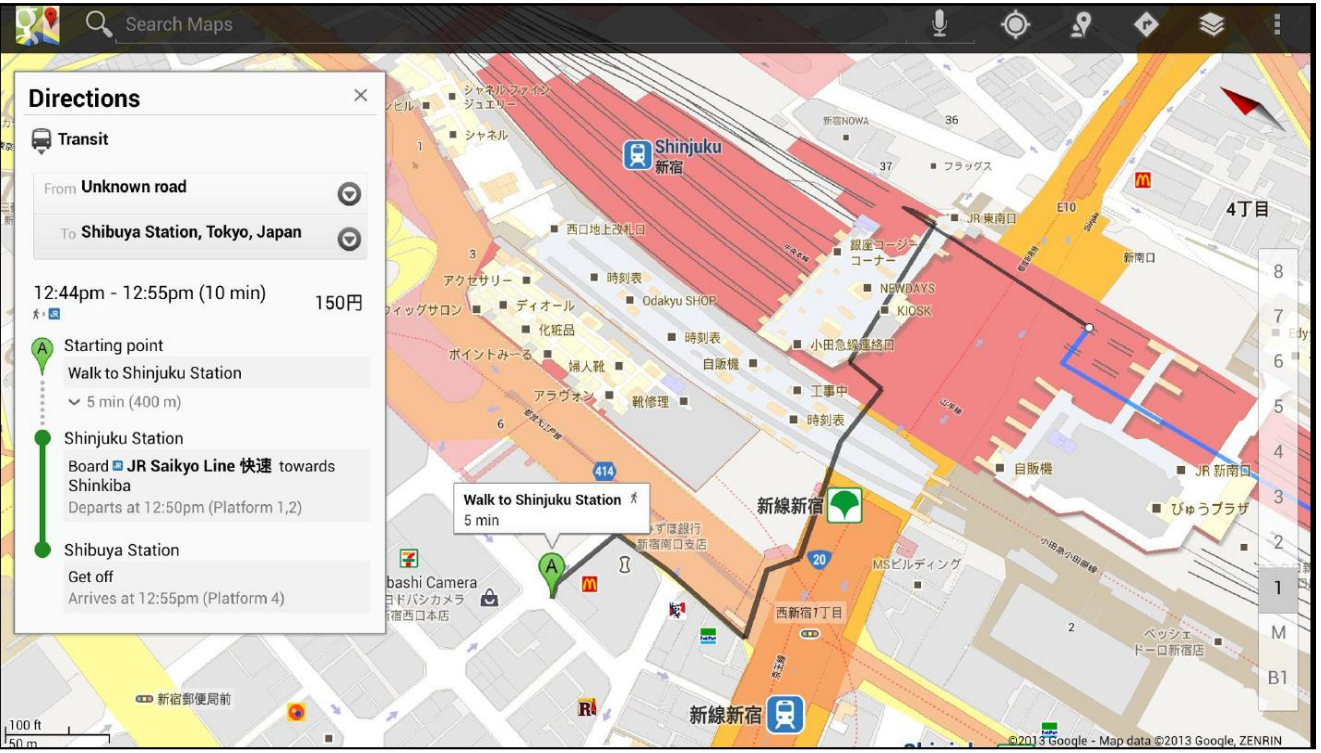


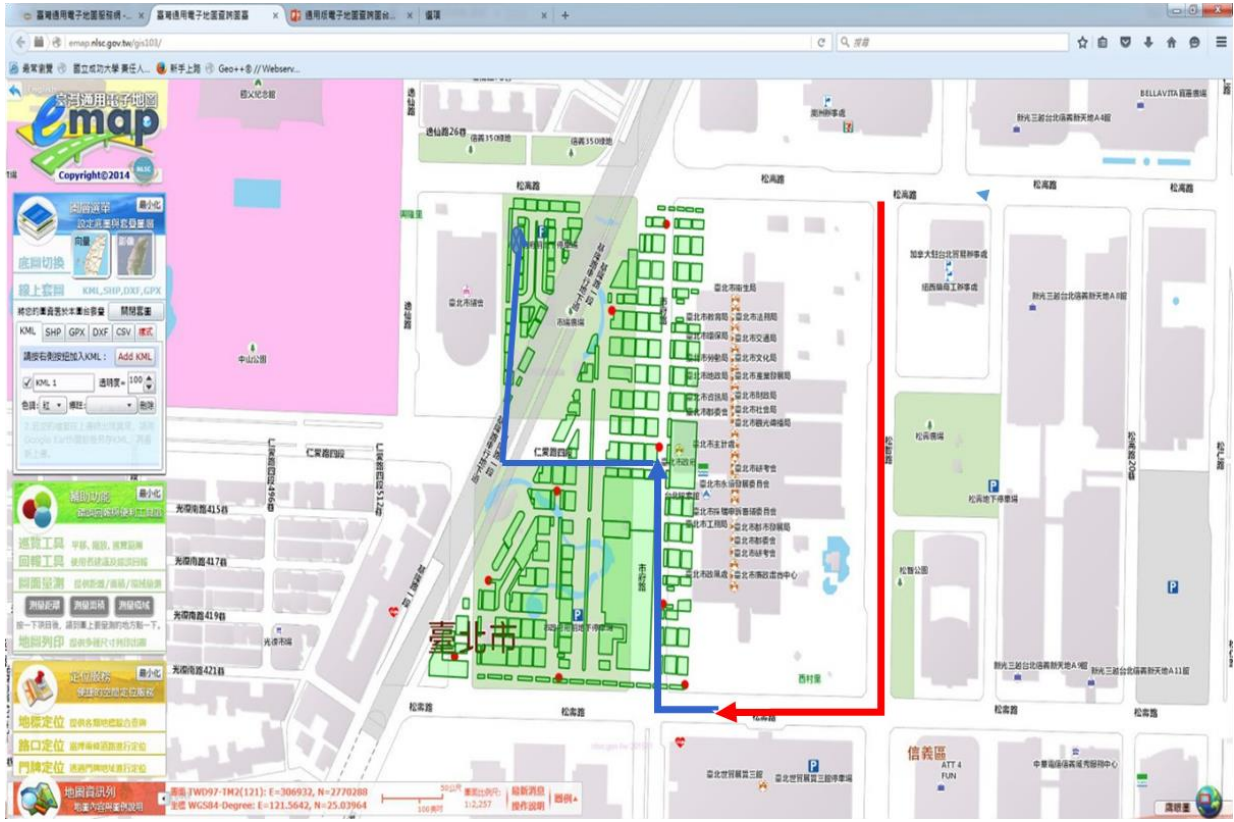


< 1m accuracy, efficient and pervasive infrastructure are key attributes for adoption

室內製圖系統

- 無縫圖資的需求

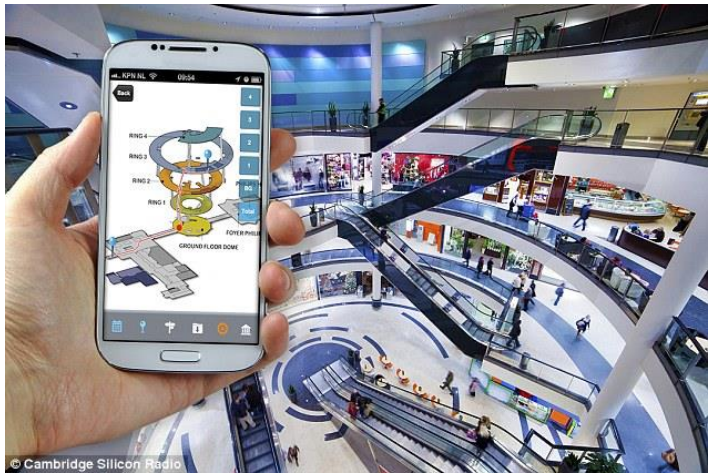




2017/2/18

室內製圖系統

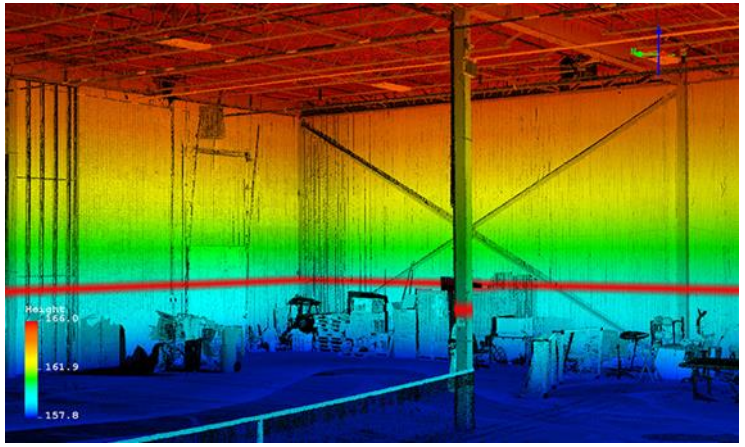
- 適用室內LBS定位技術之特色 (Schutzberg,2013)
  - GPS 室內無法妥善運作
  - RF派室內定位技術與GPS原理相似
  - 燈與磁場強度特徵可以輔助定位
  - RFID與慣性導航運作原理完全不同
  - RF派定位技術只能提供位置，無法提供姿態
  - 最好的室內外無縫定位引擎是複合式的架構
  - 此類技術之需求快速成長
  - 主要的科技大廠大力布局發展相關應用與技術
  - 美國FCC在發展緊急救難用的室內定位技術
  - **需要室內平面圖**



http://harrypotter.wikia.com/

室內製圖系統

- 專業室內移動製圖系統
  - Trimble所發展的室內移動製圖系統(Trimble Indoor Mobile Mapping Solution)，此系統搭載光達、全景相機、慣性測量儀與輪速計；因本系統強調室內製圖之應用，所以就不搭載GNSS接收機



TIMMS™ COMPONENTS

Mobile Unit & Mast

TIMMS aquisition system
- Inertial Measurement Unit (IMU)
- POS Computer System (PCS)
- LiDAR Control Systems (LCS)

One LiDAR
- Maximum range >130m
- Resolution at 10m <5mm
- Resolution at 25m <12mm
- Ranging error ±2mm
- 300° vertical field of view in 0.009° steps
- Max vertical scan speed 97Hz

One spherical camera (6 camera configuration)
- Field of View (FOV) >80% of full sphere
- 2 MegaPixel (MP) per camera
- Six (6) 3.3 mm focal length
- 1 meter/second (Up to 4 FPS)

(摘錄自https://www.trimble.com)

室內製圖系統

- 專業室內移動製圖系統
  - Leica所發展的室內移動製圖系統(Trimble Indoor Mobile Mapping Solution)

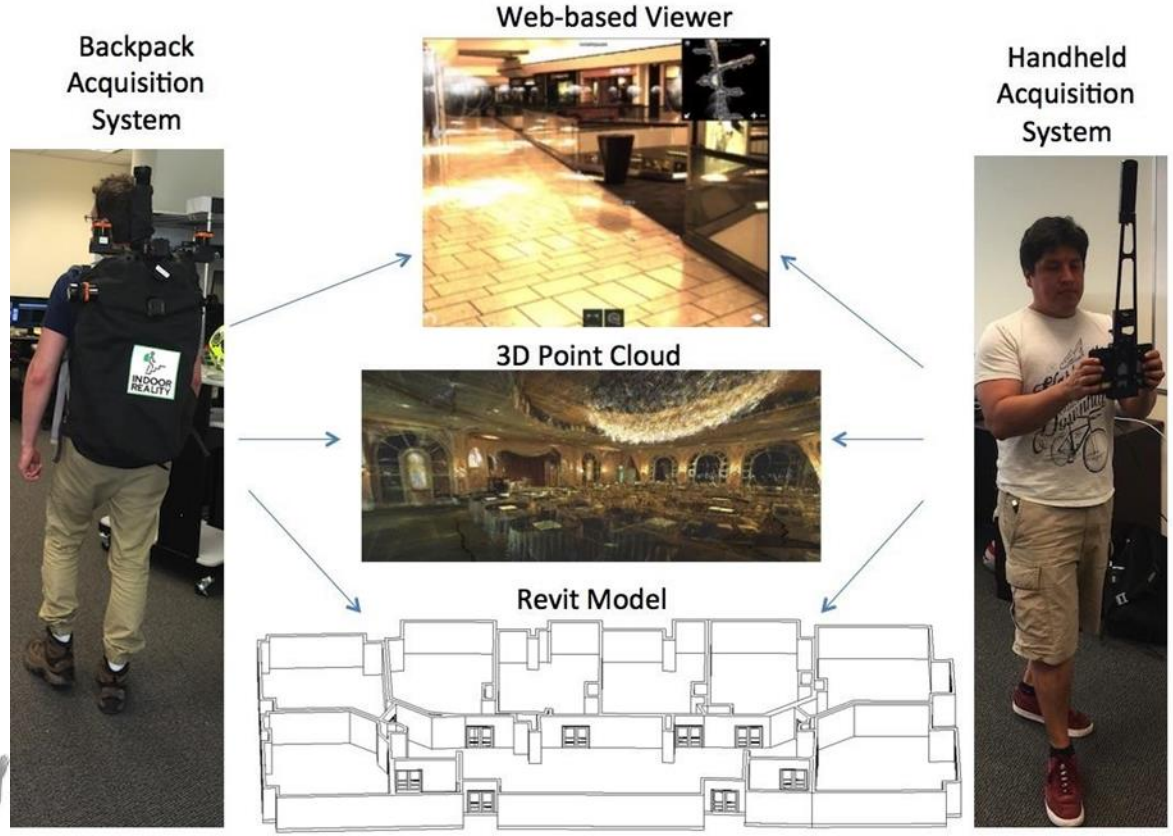
ACCURACY	
Relative accuracy	2 cm – 3 cm for outdoor and indoor
Absolute position accuracy outdoor	5 cm
Absolute position accuracy indoor (SLAM based without control points)	5 cm to 50 cm for 10 minutes walking, minimum 3 loop closures or double passes conditions A variety of factors can influence a trajectory accuracy negatively including: • Small rooms or hallways • A need to pivot while walking • Stairs and uneven pavement • Extremely smooth or blank surfaces • Surfaces too far from the scanners • Fast vertical movement - elevators are not supported Under typical indoor conditions, the lower range of the accuracy specification can be achieved.

CAMERA SENSOR	
Number of cameras	5
CCD size	2046 x 2046
Pixel size	5.5 x 5.5 microns
Maximum frame rate	2 fps x camera, equal to 160 M pixels x second
Lens	6.0 mm focal
Coverage	360° x 200°

SCANNER	
Type	Dual Velodyne VLP-16
FOV horizontal / vertical	270°/ 30° (± 15°) per scanner
Channels	16
Acquisition	600,000 pts/sec
Frequency	10 Hz
Range	Usable range: 50 m

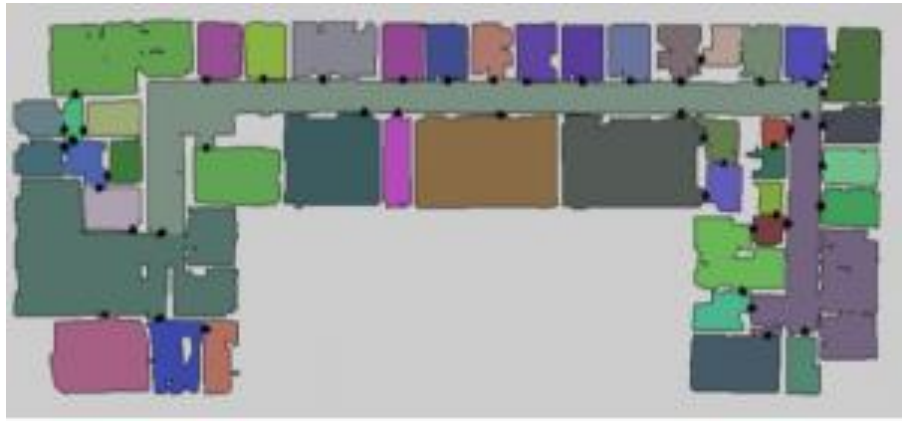
室內製圖系統

- 專業室內移動製圖系統
  - *Indoor reality*



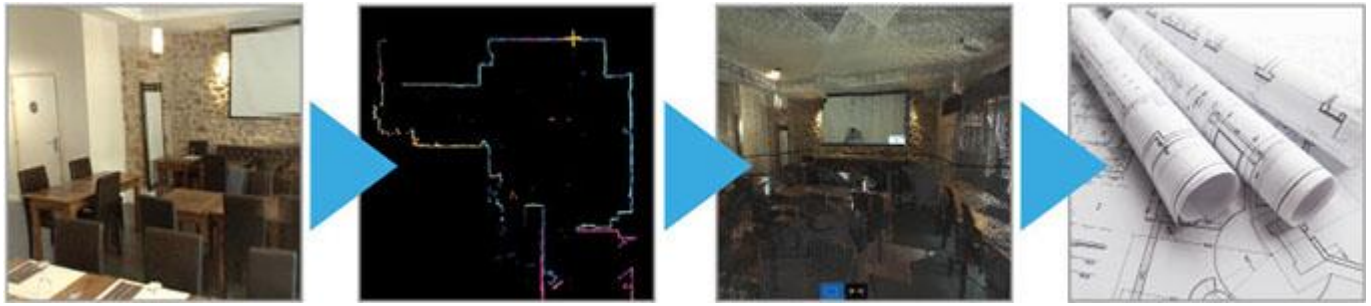
Fast, Automatic Reality Capture Engine → Rich maps / Multimodal Fingerprint Generation → Multi-Sensor Fusion for Indoor Positioning

Slow, Labor-intensive Floor Plan Generation → Manual, Slow Fingerprint Generation → Single Sensor Indoor Positioning



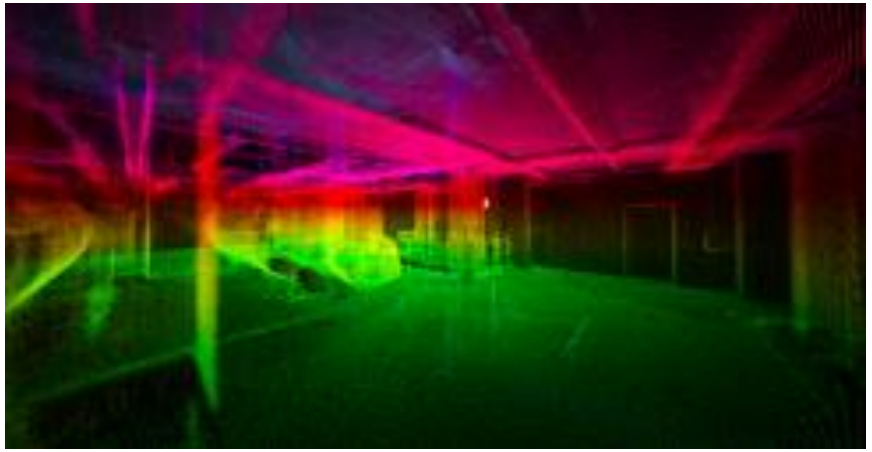
室內製圖系統

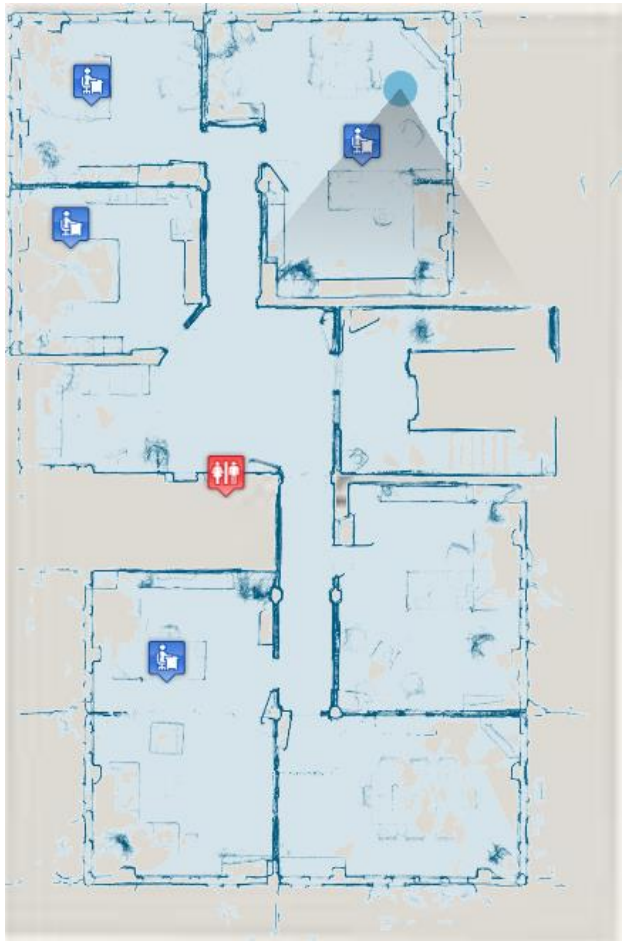
- 專業室內移動製圖系統
  - iMS 3D, Viametris



室內製圖系統

- 專業室內移動製圖系統
  - *NaVvis*



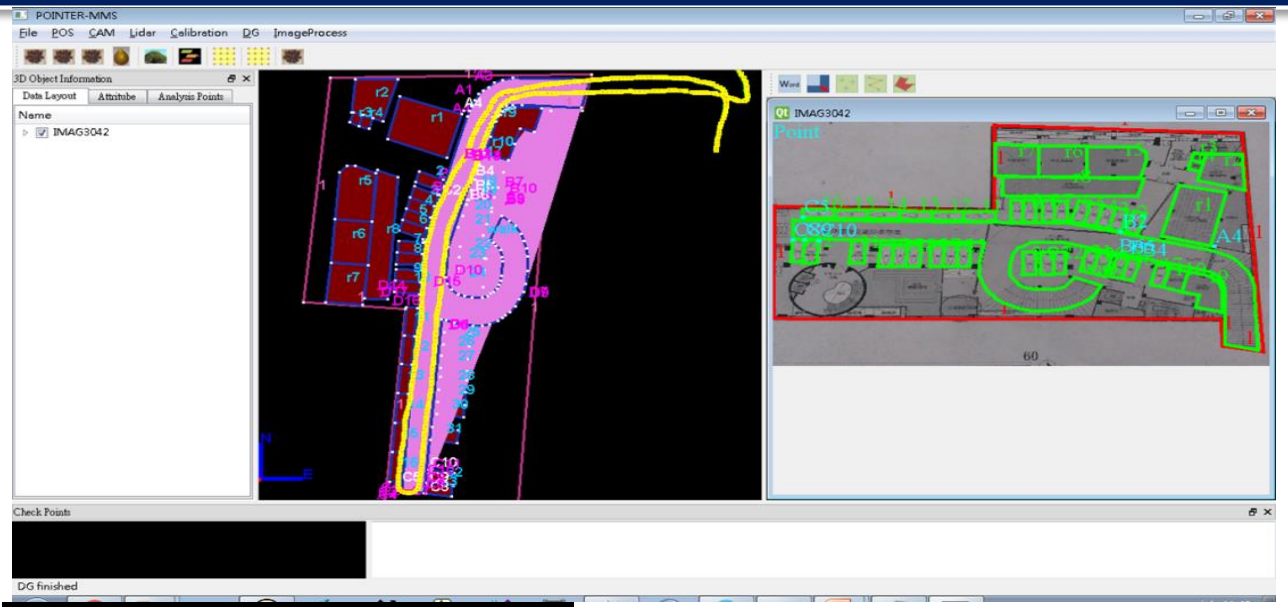


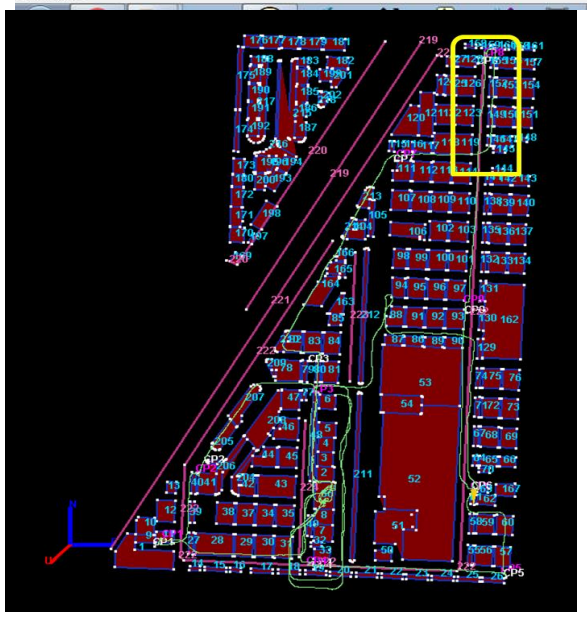
室內製圖系統

- 專業室內移動製圖系統
  - Googles Cartographer
    - Google所發展的室內移動製圖系統(The Cartographer)，此系統搭載光達與慣性測量儀；因本系統強調室內製圖之應用，所以就不搭載GNSS接收機。在這些感測器的背後，是一種被稱作“同時定位與製圖”（SLAM）的技術
    - 背上這款背包，你可以拍攝你所看到的室內每一個角落，從而即時生成平面圖。並且，你還可以在室內地圖上添加資訊點，比如你可以標記酒店的房間號、博物館的展覽品。即時生成室內平面圖實際上也不是Cartographer首創。
    - Google發佈的Tango計畫就是利用配備在Android手機上的3D感測器來製作室內地圖。
    - Tango項目主要著眼在通過手機，將物理世界與虛擬場景結合起來，而Cartographer主要被用作室內地圖的製作，因此Google表示兩個專案是完全分開的。

室內製圖系統

- 專業室內移動製圖系統
  - NCKU system



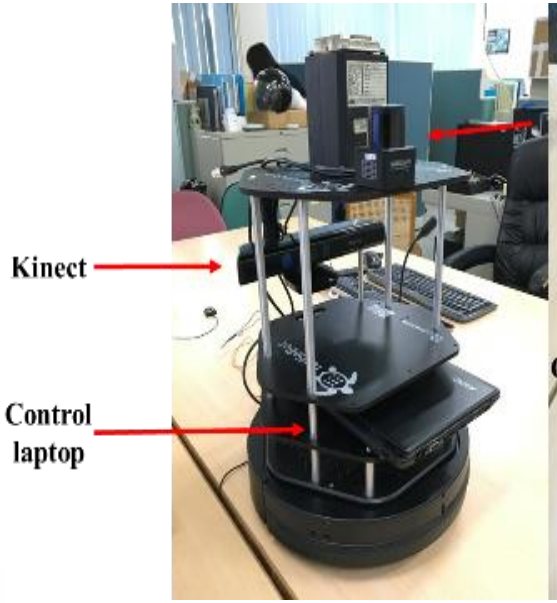


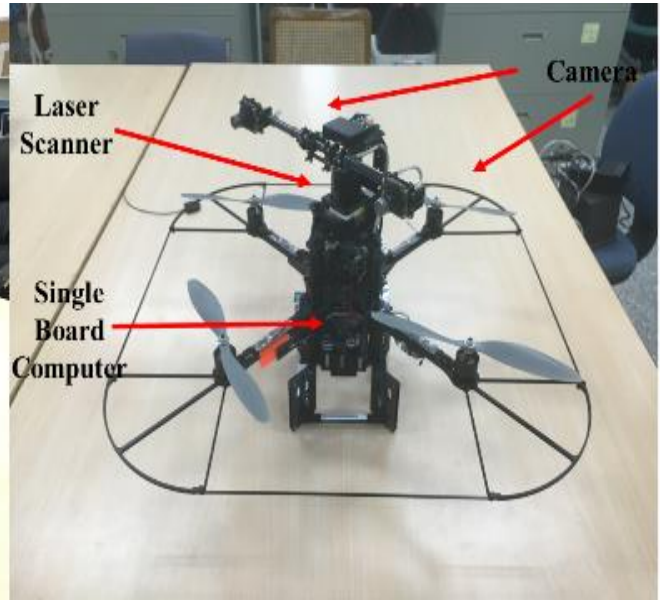
20 minutes, about 500 meters

Number: 24					
(meter)	E	N	H	2D	3D
AVG	0.016	-0.076	0.001	0.078	0.078
STD	0.283	0.266	0.137	0.388	0.412
RMS	0.278	0.271	0.134	0.388	0.41

展望

- 新世代的行動測繪技術有三個重點
  - 其一為滿足室內與室外兼顧的無縫製圖應用之需求
  - 其二為使用超低成本且大量生產的感測器
  - 其三則為無人載具之應用以進一步降低作業成本。





展望

Payload

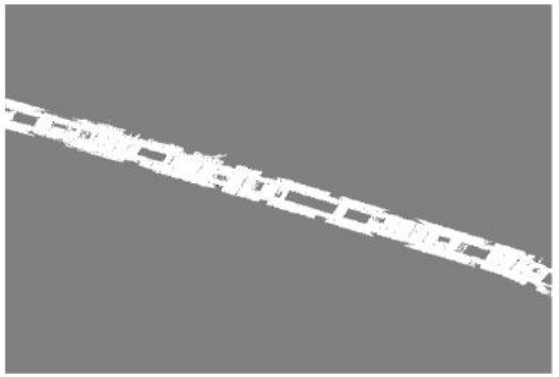
INS/GNSS

Lidar System

Technology

Mobile Mapping

Grid-based SLAM

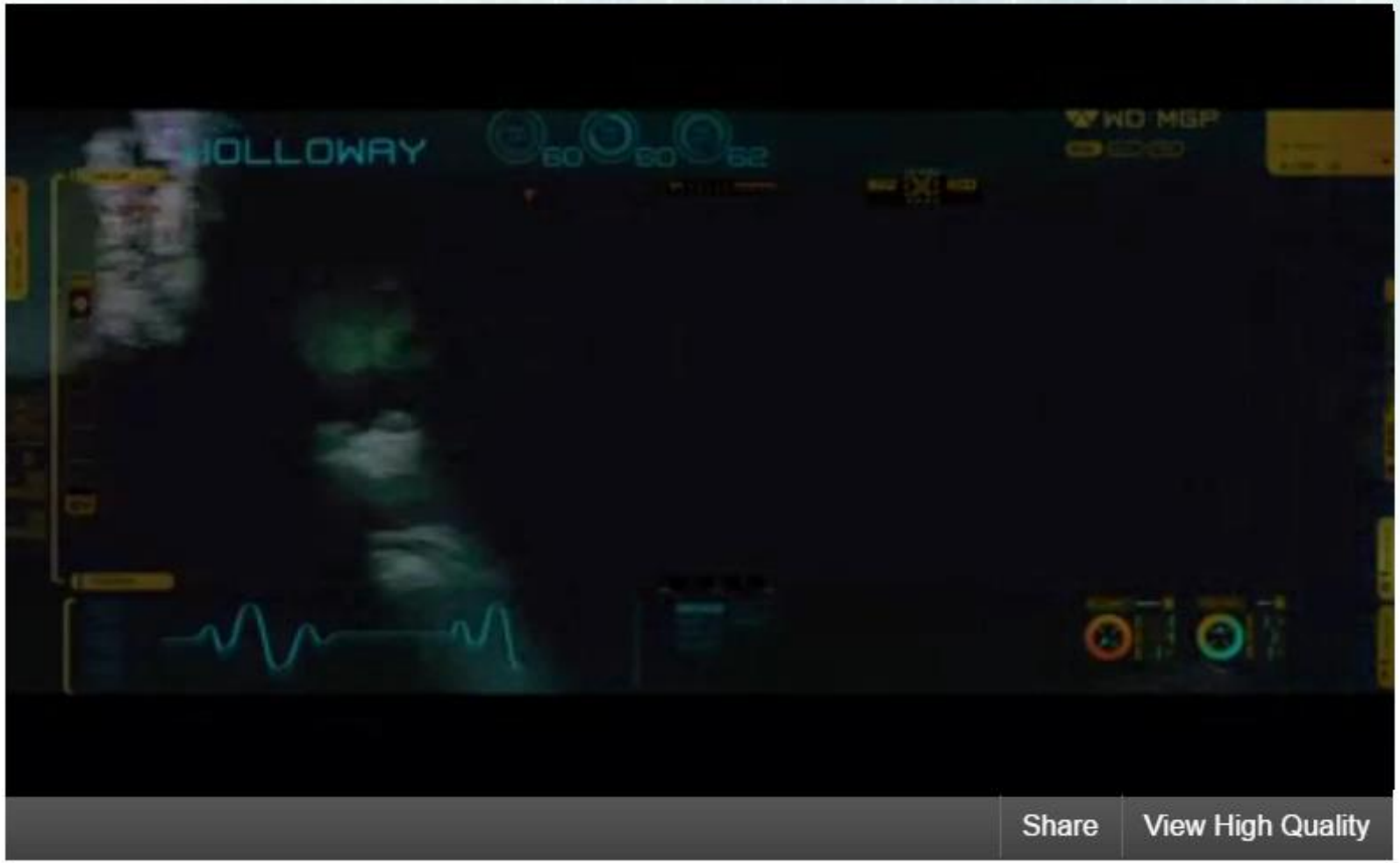


Gird Map

Floor Plan

展望

3D mapping technology in Prometheus



感謝聆聽