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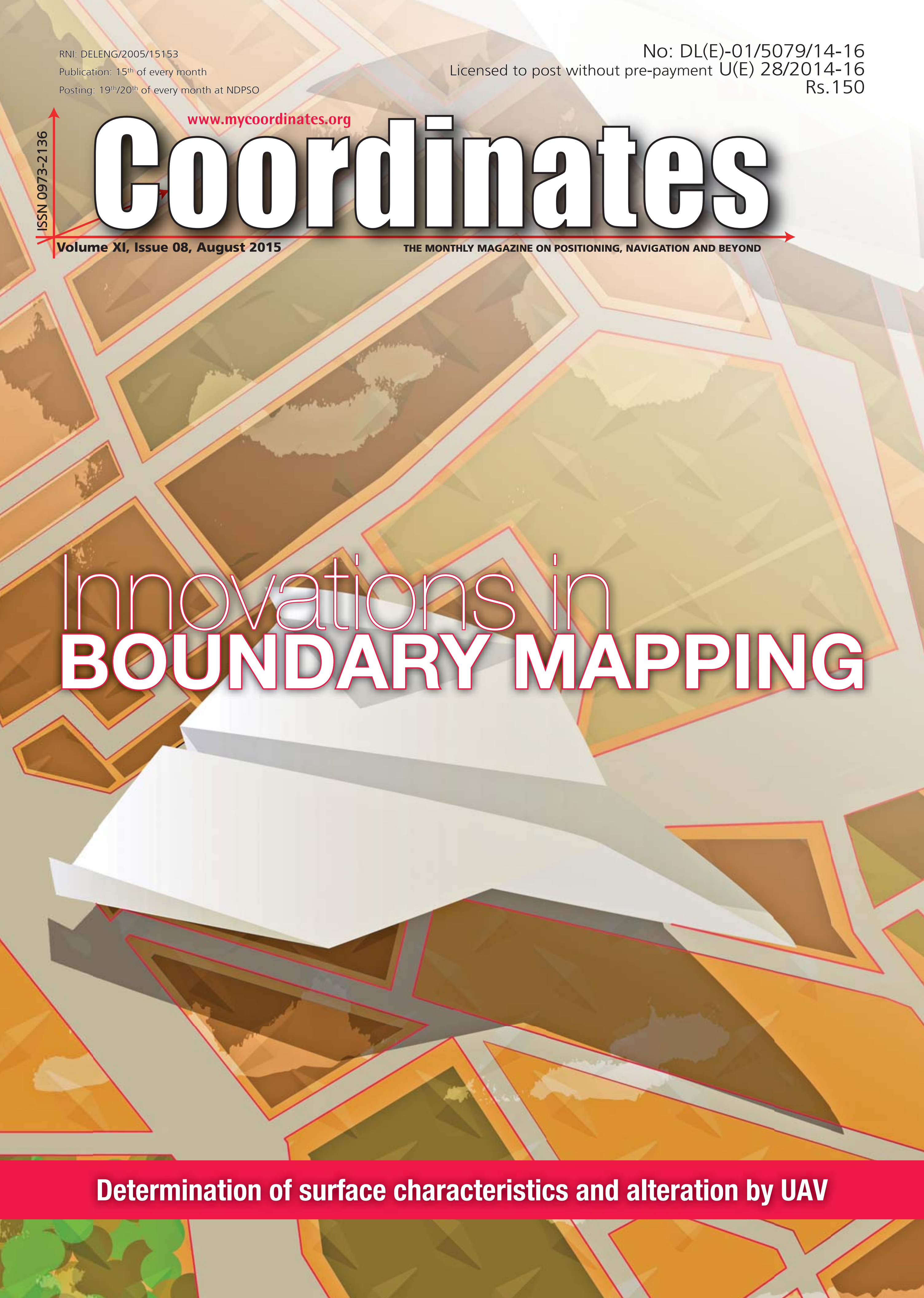

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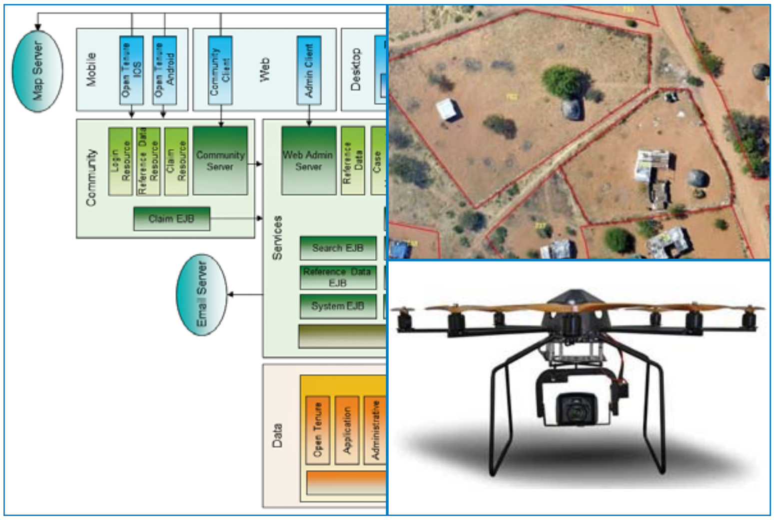

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## Articles



## Columns



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# UAV: It's flying!

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Of UAV/UAS applications.

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We present two such applications,

One in geological characterization

And other in cadastral surveying.

It appears that

UAV is gradually creating its space

And expanding it too.

**Bal Krishna, Editor**
**bal@mycoordinates.org**

# Multi-Constellation GNSS based on next generation RAIM

This paper proposes different operational scenarios that allow to better characterisation of ARAIM performance to meet RNP0.1 requirements as well as current ADS-B mandates. The promising results are used to initiate practical implementation analysis and trade off discussion about the ARAIM architecture for H-ARAIM development in a civil aviation receiver

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Because receiver autonomous integrity monitoring (RAIM) techniques are based on measurement redundancy, multi-constellation signals will have a positive impact in principle on the integrity monitoring performance of RAIM algorithms. Increasing reliability and resilience of next generation GNSS services is an agreed objective of the Global Air Navigation Plan agreed by ICAO member states. Service robustness is also a key performance indicator as introduced in the GPS-Galileo Concept of Operation developed by the EUROCAE WG62.This includes supporting approaches to landing with lateral as well as vertical guidance to achieve an increased level of safety and other operational and environmental benefits. However, current assumptions being used for RAIM based on single frequency GPS no longer hold true in a multi-constellation architecture. Consequently, this paper investigates updates required to implement future multi-constellation RAIM algorithms and evaluates associated system implications and performance.

Separate from any benefit has been recognized within standardisation bodies such as RTCA SC 159 and EUROCAE WG62, that multi-constellation and multi-frequency technology (MCMF) brings issues concerning avionics processing power, complexity of operational modes and the number of core constellations to be used. Furthermore, current investigations on MCMF Advanced RAIM (ARAIM) for vertical approach guidance have introduced a ground segment or Integrity Support Message (ISM) which increases cost and complexity and may impact implementation timescales. While the ISM does provide flexibility which has the potential to reduce the cost of future upgrades, it is not sure if and in which form it is required for horizontal guidance and positioning applications. The paper evaluates these trade-offs focusing in particular on horizontal positioning and associated implementation issues including an evaluation of operational requirements in light of how positioning performance impacts the quality of aircraft flight path guidance.

Based on these identified system trade-offs, the paper evaluates the achievable level of performance for various navigation and surveillance operations in several operational contexts. The operational contexts cover dual frequency test case, single frequency test case, nominal and degraded constellation configuration and different failure scenarios from optimistic to pessimistic. The idea behind the development of those operational contexts is to get a clear picture of the needs of horizontal advanced RAIM to sustain robust horizontal operation in civil aviation. An analysis of the results obtained under those operation contexts is performed leading to recommendations on the H-ARAIM concept discussion in the Working Group C (WGC) of the EU-US Cooperation on Satellite Navigation.

## Mission requirements description

**Table 1: NSE requirement evaluation**

| | En-route, RNP5 | TMA RNP 1 | NPA manual | RNP APCH auto | RNP 0.1 | Appr-LP/LPV | ADS-B |
|---|---|---|---|---|---|---|---|
| RNP (2σ, r | 5.00 | 1.00 | 0.30 | 0.30 | 0.10 | 0.02 | 0.05 |
| | naut mi | naut mi | m | m | m | m | m |
| NSE | 4.5317 | 0.9423 | 346 | 300 | 92 | 19 | 92 |
| FTE | 2.0353 | 0.2956 | 433 | 466 | 160 | 36 | N/A |
| PDE | 0.5665 | 0.1571 | 43 | 38 | 12 | 2 | N/A |

ARAIM is being designed to globally provide localizer performance with vertical guidance (LPV) approaches. It also includes a horizontal only guidance function. The development of such techniques highlights limitations to the current RAIM function already standardised for non-precision approach. Indeed, RAIM algorithms operating on the basis of only one constellation (i.e. GPS), have been built on the assumption of a single satellite failure with no consideration for a GPS constellation-wide failure. Considering the safety criticality of the operation served by GPS + RAIM equipment, those assumptions were acceptable. In a multiple constellation environment however, this may not be the case because an overall failure of a given constellation will not be observable in the range measurements of the other constellation. This could induce non acceptable errors. Considering the number of satellites signal available at the receiver antenna in a multiple constellation environment, the assumption of only a single satellite fault at a given time also becomes difficult to justify considering current core constellation standards or observation [SPS] [Heng]. In that perspective, standardisation bodies and civil aviation institution have identified that advanced RAIM algorithm are of interest to augment new generation of multi-constellation equipment even in case when precision approach is not the targeted operation.

In addition, ARAIM concept [GEAS] introduces an ISM component that should provide to the user information from ground observations to help the user algorithm meeting LPV requirements. The current work on ISM such as its architecture and means of dissemination show that this component may not be fully defined in a 2020 timeframe. Indeed, some questions linked to the certification, feasibility, sovereignty have been asked and are not trivial to answer. Nevertheless, in order to find a positive trade-off in the a quick implementation of ARAIM in a 2020 timeframe, it is of interest to investigate if a solution can be described obviating the need for a dynamically updatable ISM component for horizontal-only based operations.

### Navigation operations

It is well known that current RAIM augmentation may lead to RAIM operational holes for non-precision approach especially when a normalised minimum GPS constellation is taken into account [DO229D]. In that purpose lateral navigation type of operation which provides requirement equivalent to non-precision approach in terms of alarm limit is of interest. Performance results for LNAV can be used to assess the robustness of H-ARAIM solution.

In addition, investigations have been conducted to identify additional navigation operations that may become achievable with DFMC + ARAIM equipment. The International Civil Aviation Organisation (ICAO) has defined in its Performance Based Manual (PBN) [PBN], civil aviation needs in terms of navigation. The most stringent horizontal only positioning performance level that could be found is called RNP 0.1 NM. The RNP 0.1 requirements are specified for the overall aircraft meaning that it refers to the total system error including the navigation system error (NSE), path definition error (PDE) and the flight technical error (FTE). The NSE is caused primarily by the position determination function which, in our case comprises GNSS DFMC + ARAIM. The FTE is a function of the aircraft system architecture and equipage level, specifically the design of the flight guidance and control system.

For RNP0.1 operation, the overall (TSE) accuracy required is ±0.1 NM (95%) and the integrity required is ±0.2 NM ($1\text{-}10^{-5}$). An analysis has been conducted to deduce, from different aircraft architectures, the NSE requirements for different PBN applications including RNP 0.1 (see [PBN]). The outcome of the analysis has been presented to the EUROCAE WG62 meeting [EUROCAE]. The group provided as a feedback that the information used in the standards-bibliography to deduce the NSE was obsolete given current equipment performance but, in the meantime, no new reference can be made available.

Subsequently, no consensus could be reached with the aircraft OEM on revised or improved allocation values. It was therefore decided to follow the WGC ARAIM TSG 50/50 split [MSII] of the TSE requirement among the NSE and FTE to assess the availability of the DFMC + ARAIM equipment toward RNP0.1 operation.

Table 2 summarize the operational requirement of the navigation operation evaluated in this article.

### Surveillance operation

Although GNSS is associated primarily with navigation, GNSS is also the backbone of Automatic Dependent Surveillance – Broadcast (ADS-B) applications. As such, GNSS positioning and track-keeping functions are no longer "confined" to navigation enablers but become an ATS surveillance enabler. ADS-B is recognized as a key enabler for new surveillance

Table 2: Navigation Position Determination Requirements

| | Accuracy (m) | Alert Limit (m) | Integrity Risk |
|---|---|---|---|
| LNAV | 220 | 556 | $10^{-7}$/hour |
| RNP 0,1 | 92 | 184 | $10^{-7}$/hour |

Table 3: Surveillance Requirements [REF NSP paper]

| | Accuracy (m) | Alert Limit (m) | Integrity Risk |
|---|---|---|---|
| Europe Mandate | 185 | 1111 | $10^{-7}$/hour |
| US Mandate | 92 | 370 | $10^{-7}$/hour |

applications to improve the Air Traffic Management (ATM) system.

Although GNSS is not a minimum requirement to support ADS-B applications, in practice, the information transmitted through ADS-B will actually be based on GNSS (assumed to be GPS in current RTCA/EUROCAE standards). Consequently, any variations in the GNSS performances will have an effect on ADS-B operations.

Different countries in the world have started to develop ADS-B implementation through mandates based on current standards. Two types of mandates have been issued currently:

- ADS-B mandate targeting non-radar airspace with the objective to provide radar-like separation services (e.g. Australia, Canada, Singapore, Fiji, Vietnam, etc.).
- ADS-B mandate targeting ADS-B use in addition to radar and not as the only surveillance source. This kind of ADS-B mandate has been issued in Europe and in the United States.

The second case is the most constraining one based on RTCA DO-260B and EUROCAE ED-102A [DO 260]. Recent activity indicates that there may be issues to satisfactory meet the US ADS-B mandate with current GPS+RAIM equipment in the long term. This on-going analysis requires further investigation and evidence. Nevertheless, there is an interest to investigate if DFMC + ARAIM significantly improve the performance and robustness of such operations.

Table 3 summarizes the operational requirements of the ADS-B mandates as evaluated in this article.

## GNSS environment and operational scenarios

This section details the GNSS operational environment that has been considered to assess the performance of DFMC+ARAIM equipment for the navigation and surveillance application introduced in previous section. Operational scenarios have been set up based on the defined GNSS environment in order to obtain a better knowledge of the performance of the ARAIM algorithm in nominal conditions but also in potential reversion mode of the future DFMC + ARAIM equipment. The method adopted to build those scenarios has been established to assess the sensitivity of the algorithm towards the receiver environment and operational constraints.

### GNSS environment

The GNSS environment retains for the assessment of ARAIM performances is a dual frequency multi-constellation system (DFMC) that is expected to be available in a 2020 timeframe. Multi-constellation refers to GPS and Galileo in this article. Multi-frequency refers to L1/L5 frequencies in the GPS case and E1/E5a frequencies in the Galileo case.

It is assumed that future receivers will be capable to provide sufficient channels to be capable to track all satellites in view, even if maybe not all of them will be processed. An "all-in view" approach is adopted with a receiver mask angle of 5° for GPS and Galileo.

GPS constellation is simulated according to GPS SPS document [SPS] leading to a nominal case of 24 satellites or an extended case of 27 satellites. GPS 24 satellites configuration doesn't represent a minimum guaranteed state. This configuration is supposed to be available approximately 95% of the time. There is a non-negligible probability of approximately 3.5 % that the constellation may downgrade to 23 satellites. In that respect, 23 GPS constellation case is also considered in the study.

Galileo constellation specification has recently been changed from a 27 satellites constellation to a 24 satellites constellation [IOV]. The European commission adopted a step wise approach for the deployment of the Galileo system leading to 2 major milestones: FOC1 (or IOC) and FOC [IOV]. FOC1 configuration is defined with 18 satellites:

- Plane A / Slots 2, 3, 5, 8
- Plane B / Slots 2, 3, 4, 5, 6, 8
- Plane C / Slots 1, 2, 3, 4, 5, 6, 7, 8

FOC configuration is based on 24 satellites (every 8 slots in the 3 orbital planes) plus 6 spares satellites. Almanac information on the Keplerian coordinates associated to this new satellite configuration is provided in [IOV]. The FOC configuration represents a priori a minimum configuration of the constellation as 2 spares per orbit will be present to replace any faulty satellite. The constellation management plan currently anticipates that a new launch of a spare satellite will be done as soon as the two spares on one orbit are used for operation. This would maintain the number of satellites in that orbit at 8 + 2. There is a risk that a third satellite fails before new spare satellites are deployed in the orbit. This risk is linked to the reactivity of the Galileo program to launch two additional spares when all spare satellites in one orbit are used. In that respect a 23 satellites configuration is considered as degraded configuration in the study. More information on this 23+23 scenario case is presented in the next section.

### Operational scenarios

The operational scenarios are elaborated such that an analysis of the robustness and operational benefits of an ARAIM DFMC receiver for horizontal based operation is possible. First of all, the models representing the error budget associated to the various sources of positioning error affecting the satellite to ARAIM user receiver channel per constellation have to be defined. The measurement error budget has to take into account the following contributions:

- Orbit determination and synchronization equivalent error
- Troposphere residual error
- Ionosphere residual error
- Multipath residual error
- Receiver noise residual error

Most of conventional RAIM measurement model assumes that satellite ranging errors have a zero mean Gaussian distribution [DO 229]. For integrity monitoring of more stringent applications than non-precision approach, this assumption has been criticised [GEAS]. Indeed the GEAS group explicitly considered the presence of biases in the range measurements and has designed a RAIM algorithm to protect against the worst case distribution, which occurs when the contributions from these biases to user position error all have the same sign. Therefore, each satellite ranging error is modelled as a combination of random and bias error components. This philosophy has been kept in the WGC ARAIM algorithm [Blanch]. As it follows from statistical analysis, the impact of bias error components increases the probability of false alarm and, also the probability of missed detection. Two these factors lead to the reduction of the detection function availability while providing better protection level figure.

The global pseudorange error variance of the random contribution is computed as follow:

$$\sigma^2_{\mathrm{UERE}} = \sigma^2_{\mathrm{URA}} + \sigma^2_{\mathrm{iono}} + \sigma^2_{\mathrm{RX}} + \sigma^2_{\mathrm{MP}} + \sigma^2_{\mathrm{tropo}}$$

The nominal bias parameter ($b_{nom}$) represents the overbounding terms of all bias terms that could affect the pseudorange measurement.

Table 4 provides the references of the models used to define the pseudorange error variance of the ARAIM user receiver:

**Table 4: ARAIM Measurement Model**

| | Error Sources | Settings and References |
|---|---|---|
| **Measurement Model** | Troposphere | DO 229D model [DO 229] |
| | Ionosphere | $\sigma_{I,L1}$ = 12 m or 27 m<br>$\sigma_{I,L5}$ = 18 m<br>$\sigma_{I,E1}$ = 10 m or 27 m<br>$\sigma_{I,E5a}$ = 18 m |
| | Multipath and Receiver noise | SESAR 9.27 recommendations |
| | Satellite clock and ephemeris | 1 m to 6 m |
| | Nominal Bias | 75 cm to 1 m |

The operational scenarios have been elaborated taking into account the potential nominal and fall back mode of the future DFMC receiver and the main inputs related to the ARAIM algorithm processing or the information provided by the ISM in the ARAIM concept of operation [MSII]. Four categories of scenarios have been characterised:

- Constellation/Satellite geometry impact scenario
- Single Frequency impact scenario
- Constellation/Satellite failure impact scenario
- Satellite clock and ephemeris sensitivity scenario

## Constellation/Satellite geometry impact scenario

The number of satellites available has usually a significant impact on the autonomous integrity monitoring performance as those techniques rely on the redundancy of the measurements. Today the GPS constellation is very well populated. Nevertheless it seems fair to consider only 24 satellites (eventually extended to 27) for performance assessment as soon as the dual frequency case is the nominal mode of operation. The step wise approach adopted for Galileo may lead to an initial state of 18 followed by a final state of 24. There is an interest to mix the various cases in order to analyse the potential impact of such parameter on ARAIM performance.

As described in the previous section, a 23+23 configuration may be experienced by ARAIM user. Scenarios have been elaborated on this configuration. The methodology used for the 23+23 simulation is to first identify the couple of GPS and Galileo satellite that that will impact the most the DOP when they are removed from the solution at each epoch and location. Based on this result, the ARAIM algorithm is launched in a second step without this specific couple of satellite at each epoch and location. This method is not a practical case but will provide conservative results in terms of performance degradation at each location in a 23 + 23 satellite scenario. Another method consisting in removing the satellite PRN 2 of each constellation is also considered.

The following scenarios have been simulated:

- Simulation 1.1: 24 GPS + 24 GAL
- Simulation 1.2: 24 GPS + 18 GAL
- Simulation 1.3: 27 GPS + 24 GAL
- Simulation 1.4: 27 GPS + 18 GAL
- Simulation 1.5: 23 GPS + 23 GAL with the DOP method
- Simulation 1.6: 23 GPS + 23 GAL removing PRNs 2

## Single frequency impact scenario

The ARAIM receiver may fall back to a single frequency mode in case of interference in one of the two frequencies used. In that respect, the following scenarios have been considered:

- Simulation 2.1 (Nominal L1 case): $\sigma_{ionoL1}$: 12 m / $\sigma_{ionoE1}$: 10 m
- Simulation 2.2 (Worst L1 case): $\sigma_{ionoL1}$: 27 m / $\sigma_{ionoE1}$: 27 m
- Simulation 2.3 (Nominal L5 case): $\sigma_{ionoL5}$: 18 m / $\sigma_{ionoE5}$: 18 m

- Simulation 2.4 (Worst L5 case): $\sigma_{ionoL5}$: 48 m / $\sigma_{ionoE5}$: 48 m

The L5 only scenarios have been elaborated based on L1 scenario references adapted to the L5 frequency environment.

## Constellation/Satellite failure impact scenario

It has been recognized that probability of satellite failure and constellation play a significant role in the ARAIM performance for LPV operation. However, there is information available in the standards only for GPS satellite failures [SPS]. Galileo standard development is on-going on this matter and should be available in a 2016 timeframe. Consequently, there is an interest to perform a sensitivity analysis on those parameters in order to anticipate the impact that this may have on user performance.

The following scenarios are considered here with the idea GPS is more mature and measurement available that sustain low probability while it is anticipated that Galileo may not commit to the same level of probability of failure initially.

- Simulation 3.1: Reference case
  - PsatGAL / PsatGPS : $10^{-5}$
  - PconstGAL / PconstGPS : $10^{-5}$
- Simulation 3.2: Degraded Pconst effect
  - PsatGAL / PsatGPS : $10^{-5}$
  - PconstGAL / PconstGPS : $10^{-4}$
- Simulation 3.3: Degraded Galileo case
  - PconstGPS / PsatGPS : $10^{-5}$
  - PconstGAL / PsatGAL : $10^{-4}$
- Simulation 3.4: Realistic case
  - PsatGAL / PsatGPS : $10^{-5}$
  - PconstGAL : $10^{-3}$
  - PconstGPS : $10^{-8}$

## Satellite clock and ephemeris sensitivity scenario

ARAIM activity on LPV is relying on assumption that the broadcasted information on satellite clock and ephemeris error bounds (URA for GPS and SISA for Galileo) can be relaxed by comparison to the current URA broadcasted value. Measurement campaign and analysis done by Stanford University has confirmed that such assumption may be realistic. In the other hand, the results presented don't take into account the full GPS L5 constellation as it has not been fully deployed neither the Galileo satellites. Therefore, this class of scenario targets the assessment of the impact of degraded URA/SISA on ARAIM user performance. The optimistic case was derived from the WGC ARAIM TSG work whereas the realistic and worst case are derived from current GPS performance and Galileo signal in space interface control document information [Galileo].

- Simulation 4.1: Optimistic GPS and Galileo
  - URA = 1 m / URE = 0,5 m
  - SISA = 1,5 m / SISE = 0,75 m
- Simulation 4.2: Realistic GPS and Galileo
  - URA = 2,4 m / URE = 2 m
  - SISA = 3 m / SISE = 1,5 m
- Simulation 4.3: Worst case Galileo
  - URA = 2,4 m / URE = 2 m
  - SISA = 6 m / SISE = 3 m

## Summary of the operational scenarios investigated

Table 5 summarizes the operational scenarios defined in this article.

**Table 5: List of Operational Scenarios**

| Class of Scenario | Description |
|---|---|
| **Constellation/ Satellite geometry impact scenario** | 1. Simulation 1.1: 24 GPS + 24 GAL<br>2. Simulation 1.2: 24 GPS + 18 GAL<br>3. Simulation 1.3: 27 GPS + 24 GAL<br>4. Simulation 1.4: 27 GPS + 18 GAL<br>5. Simulation 1.5: 23 GPS + 23 GAL with the DOP method<br>6. Simulation 1.6: 23 GPS + 23 GAL removing PRNs 2 |
| **Single frequency impact scenario** | 1. Simulation 2.1 (Nominal L1 case): $\sigma_{ionoL1}$: 12 m / $\sigma_{ionoE1}$: 10 m<br>2. Simulation 2.2 (Worst L1 case): $\sigma_{ionoL1}$: 27 m / $\sigma_{ionoE1}$: 27 m<br>3. Simulation 2.3 (Nominal L5 case): $\sigma_{ionoL5}$: 18 m / $\sigma_{ionoE5}$: 18 m<br>4. Simulation 2.4 (Worst L5 case): $\sigma_{ionoL5}$: 48 m / $\sigma_{ionoE5}$: 48 m |
| **Constellation/Satellite failure impact scenario** | 1. Simulation 3.1: Reference case<br>▪ PsatGAL / PsatGPS : $10^{-5}$<br>▪ PconstGAL / PconstGPS : $10^{-5}$<br>2. Simulation 3.2: Degraded Pconst effect<br>▪ PsatGAL / PsatGPS : $10^{-5}$<br>▪ PconstGAL / PconstGPS : $10^{-4}$<br>3. Simulation 3.3: Degraded Galileo case<br>▪ PconstGPS / PsatGPS : $10^{-5}$<br>▪ PconstGAL / PsatGAL : $10^{-4}$<br>4. Simulation 3.4: Realistic case<br>▪ PsatGAL / PsatGPS : $10^{-5}$<br>▪ PconstGAL : $10^{-3}$<br>▪ PconstGPS : $10^{-8}$ |
| **Satellite clock and ephemeris sensitivity scenario** | 1. Simulation 4.1: Optimistic GPS and Galileo<br>▪ URA = 1 m / URE = 0,5 m<br>▪ SISA = 1,5 m / SISE = 0,75 m<br>2. Simulation 4.2: Realistic GPS and Galileo<br>▪ URA = 2,4 m / URE = 2 m<br>▪ SISA = 3 m / SISE = 1,5 m<br>3. Simulation 4.3: Worst case Galileo<br>▪ URA = 2,4 m / URE = 2 m<br>▪ SISA = 6 m / SISE = 3 m |

## Simulation results and analysis

### Simulation environment

The ARAIM results that are presented in the next section has been realised based on a simulation platform implementing an ARAIM algorithm introduced in [Blanch] and using the platform configuration as mentioned in Table 6:

### Results analysis

The simulation results are provided in the core article section through tables bellow including the 99.9% horizontal protection level (HPL) figure and availability of the ARAIM user as a function of the operational requirements used in this study. The 99.9% HPL represents means the maximum of the 99.9 percentile of the HPL distribution on each user point tested over the globe. It is anticipated that such information can solve issue introduced in section 2 on the FTE/NSE requirement allocation as one can deduce the NSE achievable at 99.9% with the ARAIM algorithm for the tested operational scenario.

Maps of the HPL and HPL distribution figures are provided in addition

Table 6: Simulation environment

| | Parameters | Assumptions/Settings |
|---|---|---|
| **Simulation environment** | Simulation duration | 10 days |
| | Time resolution | 5 min |
| | Latitude coverage | [-90°; +90°] |
| | Longitude coverage | [-180°; +180°] |
| | User grid resolution | 5° by 5° |
| **Algorithm** | ARAIM user algorithm | [REF D2 7] |

Table 7: Baseline Simulation Parameters

| Parameters | Settings |
|---|---|
| **Constellation** | 24 + 24 |
| **Signals** | L1/L5 and E1/E5a |
| **URA / URE** | 1 / 0.5 |
| **SISA / SISE** | 1,5 / 0,75 |
| **Bnom** | 0,75 |
| $P_{satGAL}$ / $P_{satGPS}$ | $10^{-5}$ / $10^{-5}$ |
| $P_{constGAL}$ / $P_{constGPS}$ | $10^{-5}$ / $10^{-5}$ |

Constellation/Satellite geometry impact scenario results

| Operational Scenario | 99.9 % HPL (meters) | RNP 0.1 Availability | LNAV Availability | US ADS-B Availability | EU ADS-B Availability |
|---|---|---|---|---|---|
| **24 GPS + 24 GAL** | 20.26 | 100% | 100% | 100% | 100% |
| **24 GPS + 18 GAL** | 1830 | 48.72% | 57.50% | 53.76% | 60.76% |
| **27 GPS + 24 GAL** | 669.3 | 98.97% | 98.96% | 98.63% | 100% |
| **27 GPS + 18 GAL** | 1830 | 48.72% | 57.50% | 53.76% | 60.76% |
| **23 GPS + 23 GAL with the DOP method** | 1033 | 99.81% | 99.85% | 99.85% | 99.96% |
| **23 GPS + 23 GAL removing PRNs 2** | 770.2 | 99.85% | 99.89% | 99.85% | 100% |

Single frequency impact scenario

| Operational Scenario | 99.9 % HPL (meters) | RNP 0.1 Availability | LNAV Availability | US ADS-B Availability | EU ADS-B Availability |
|---|---|---|---|---|---|
| **Nominal L1 case** | 70.36 | 100% | 100% | 100% | 100% |
| **Worst L1 case** | 103.4 | 100% | 100% | 100% | 100% |
| **Nominal L5 case** | 85.13 | 100% | 100% | 100% | 100% |
| **Worst L5 case** | 136.7 | 100% | 100% | 100% | 100% |

Constellation/Satellite failure impact scenario

| Operational Scenario | 99.9 % HPL (meters) | RNP 0.1 Availability | LNAV Availability | US ADS-B Availability | EU ADS-B Availability |
|---|---|---|---|---|---|
| **Reference case** | 20.26 | 100% | 100% | 100% | 100% |
| **Degraded Pconst effect** | 22.15 | 100% | 100% | 100% | 100% |
| **Degraded Galileo case** | 22.33 | 100% | 100% | 100% | 100% |
| **Realistic case** | 23.08 | 100% | 100% | 100% | 100% |

Satellite clock and ephemeris sensitivity scenario

| Operational Scenario | 99.9 % HPL (meters) | RNP 0.1 Availability | LNAV Availability | US ADS-B Availability | EU ADS-B Availability |
|---|---|---|---|---|---|
| **Optimistic GPS and Galileo** | 20.26 | 100% | 100% | 100% | 100% |
| **Realistic GPS and Galileo** | 32.71 | 100% | 100% | 100% | 100% |
| **Worst case Galileo** | 33.41 | 100% | 100% | 100% | 100% |

in an Annex section (in the box accompanying this article).

The results have been realised based on the following setting. Table 5 provides the specific parameter change state that has been set in each operational scenario. The other parameters are not changed if not indicated.

The results highlight the sensitivity of ARAIM to the constellation design and number of satellites. Under the simulation assumptions and especially considering the $10^{-5}$ Psat and Pconst parameters, the algorithm is not capable to provide a protection level when 18 Galileo satellites are simulated. An increased number of satellites don't necessarily bring additional performance benefits. Indeed, the GPS extended 27 constellations includes a downgrading geometry case with the removal of 3 nominal slots satellites compared to the nominal 24 constellation case. In general, looking at the HPL distribution shows that additional satellites decrease the HPL mean but some satellites geometries are observed affecting the 99.9 statistics of the HPL which is detrimental for the final availability.

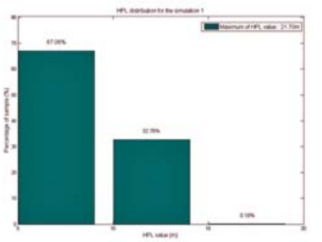
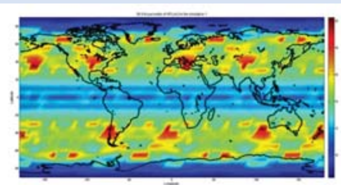
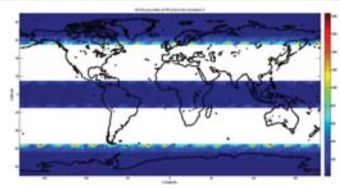
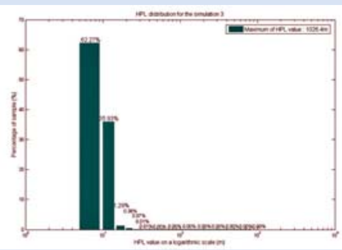
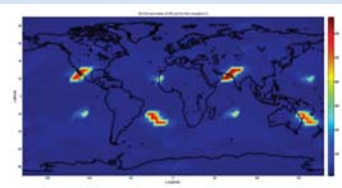
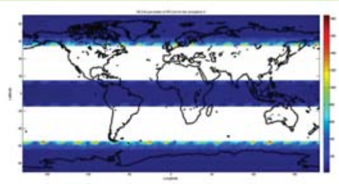
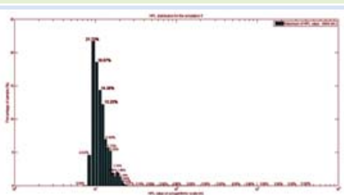
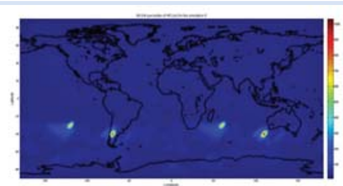
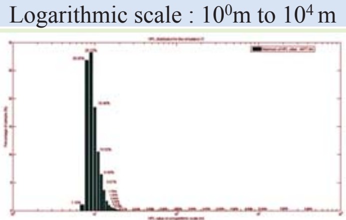
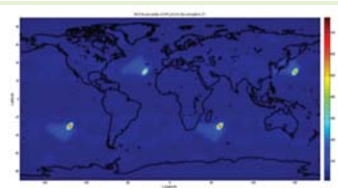
The methodology propose to assess the impact of downgraded constellation to 23 based on the DOP is more conservative than the one based on PRN 2 removal. While it doesn't represent a physical situation, it provides the benefits to show the worst case cumulated situation over the user grid of a loss of one GPS and one Galileo satellite. 99% availability is available for all operation of interest in such 23 + 23 downgraded constellation cases.

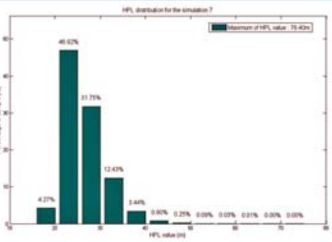
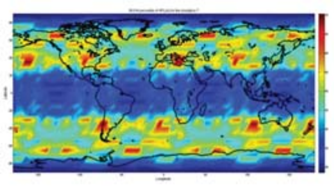
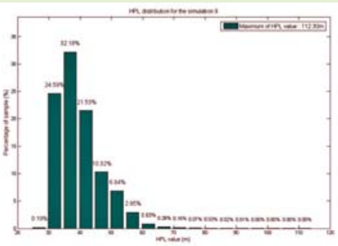
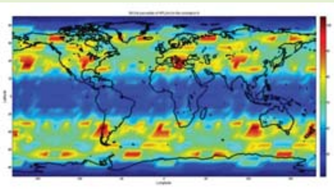
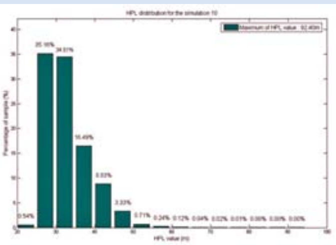
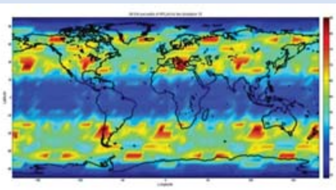
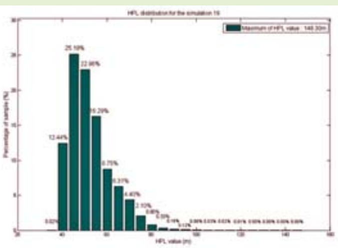
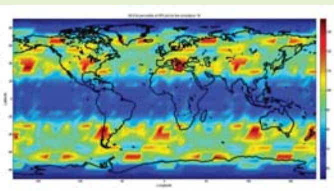
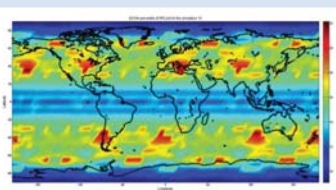
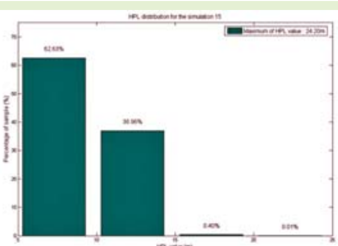
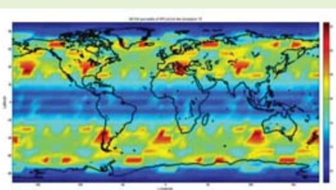
Based on a nominal 24+24 constellation, a 20 m NSE requirement is sufficient to sustain 99.9% of availability which provides a lot of margin for the FTE budget for RNP 0.1 application.

As anticipated, an increase of HPL is observed on the results compare to the dual frequency case due to the ionosphere budget error but in the meantime the availability of all

## Annex

The annex presents additional results on the protection level computed for the scenario introduced in this paper. It may be used as complementary means of analysis.

| Scenario | HPL distribution | HPL 99.9% |
|---|---|---|
| 24 GPS - 24 Gal |  Scale 0m to 20m |  Scale 8m to 20m |
| 18 Gal – 24 GPS | This histogram is unavailable because the maximum of HPL values is infinite for certain geometries. |  Scale 15m to 1800m White color on map represents data which are not numbers. |
| 24Gal – 27 GPS |  Logarithmic scale : $10^0$m to $10^4$ m |  Scale 9m to 600m |
| 18 Gal – 27 GPS | This histogram is unavailable because the maximum of HPL values is infinite. |  Scale 16m to 1800m White color on map represents data which are not numbers. |
| 23 Gal – 23 GPS with the DOP method |  Logarithmic scale : $10^0$m to $10^4$ m |  Scale 10m to 1000m |
| 23 Gal – 23 GPS removing PRNs 2 |  Logarithmic scale : $10^0$m to $10^4$ m |  Scale 10m to 700m |

| Scenario | HPL distribution | HPL 99.9% |
|---|---|---|
| Nominal L1 case |  Scale 10m to 80m |  Scale 30m to 70m |
| Worst L1 case |  Scale 20m to 120m |  Scale 40m to 100m |
| Nominal L5 case |  Scale 20m to 100m |  Scale 35m to 85m |
| Worst L5 case |  Scale 20m to 160m |  Scale 55m to 130m |
| Degraded Pconst effect |  Scale 5m to 25m |  Scale 9m to 22m |
| Degraded Psat and Pconst Galileo case |  Scale 5m to 25m |  Scale 9m to 22m |

applications has not been impacted. The 99.9 % HPL metrics indicate that more than 0.1 NM could be allocated to the aircraft FTE even in worse case without impacting the availability of RNP0.1 operation.

Both navigation and surveillance application are covered in a reverted single frequency mode making the H-ARAIM concept robust to the loss of one frequency.

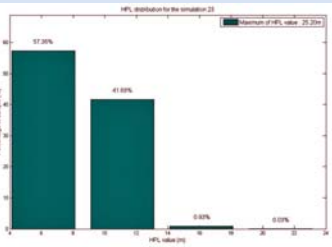
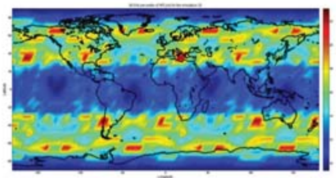
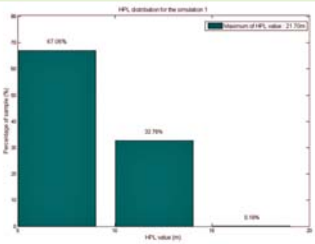
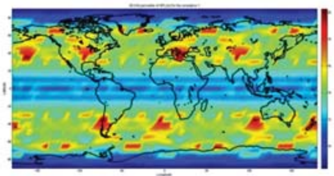
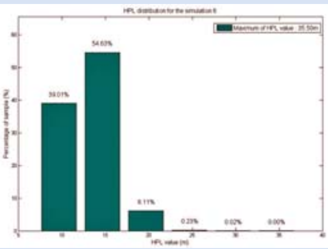
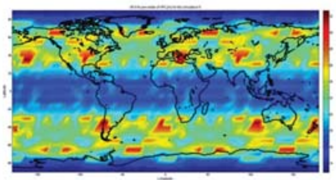
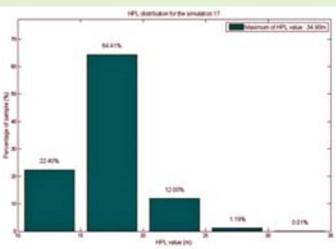
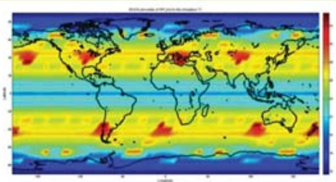
The probability of satellite failure and constellation is a key parameter in LPV 200 analysis done in the past on ARAIM. The results indicate that this is not the case for horizontal based applications as 100 % of availability is reached on all applications for each scenario. The increase of the Galileo Pconst or Psat has an impact but limited as it can be deduced from the 99.9% HPL metrics. Civil aviation may consider in the future high probability of constellation failure for a new core constellation if the second constellation is either performing at a low Pconst or has not been demonstrated to achieve a high Pconst.

Demonstration of Psat/Pconst at $10^{-3}$ or $10^{-4}$ level from core constellation service provider (CSP) may be sufficient to sustain civil aviation needs for horizontal applications.

Increase values for URA and SISA have a more significant impact on the results than low Psat/Pconst on the 99.9% HPL figure but not on the availability results. The worst case has been built upon the current GPS broadcasted URA value and the worst case SISA that could be encoded by Galileo. It results to an increase of 13 meters on the 99.9 % HPL which still provides a lot of margin compare to the requirements for all horizontal applications.

## H-araim implementation discussion

Activity realized under GEAS US program and EU US WGC have

| Scenario | HPL distribution | HPL 99.9% |
|---|---|---|
| Realistic Psat and Pconst GPS and GAL case |  Scale 4m to 24m |  Scale 9.5m to 23m |
| Optimistic URA GPS and SISA Galileo |  Scale 0m to 20m |  Scale 8m to 20m |
| Realistic URA GPS and SISA Galileo |  Scale 5m to 40m |  Scale 13m to 32m |
| Worst case URA GPS and SISA Galileo |  Scale 10m to 35m |  Scale 16m to 32m |

highlighted the need of an Integrity Support Message (ISM) helping the ARAIM algorithm to sustain LPV 200 operational requirements. The ISM should provide to all users information such as Psat/Pconst/URA based on a worldwide ground segment monitoring the core constellation signals. The information provided by the ISM could be based on CSP commitment or could be based on observation and monitoring process. In that sense, the ISM may provide to user a fair estimation of some ARAIM parameter allowing to take credit of performing constellation and to mitigate constellation with lower quality of service.

Different ISM architectures based on an “on-line” scheme or an “off-line” scheme have been introduced in [REF MSIIB]. It becomes obvious that the ISM and the means to disseminate the information is a key driver in performance/cost/complexity/readiness analysis. An initial step to take credit of the future multi-constellation and dual frequency system available consists in looking at horizontal based application performance needs and assessment of the ISM constraints to sustain those needs. The main interest was to understand if the ISM architecture developed to sustain LPV200 ARAIM operation is still required to sustain horizontal navigation based application with ARAIM. The results presented in the previous section indicate that a regularly updatable ISM as described for vertical ARAIM (V-ARAIM) may not be needed for horizontal ARAIM (H-ARAIM). When looking at the nominal constellation scenarios based on 24 satellites on both GPS and Galileo, the ARAIM algorithm is robust toward the loss of frequency and the most conservative scenario for the probability of failure and the satellite clock/ephemeris error budget. An ARAIM receiver with fixed and conservative assumption with regards to ISM parameter may be capable to sustain all navigation and surveillance requirements investigated in this paper. However, this does not exclude that an updatable ISM may be useful for other purposes.

An updatable on-board ISM provides benefits in the long term as it can mitigate changes in the quality of service of core constellation without change on the airborne equipment. Nevertheless, receiver manufacturer have expressed some concerns in RTCA SC 159 and EUROCAE WG62 on the complexity and certification burden of such implementation. A trade off may be found on H-ARAIM to set a receiver architecture that can accommodate change in the CSP performance and standardization/certification cost between a fix ISM and a complete updatable ISM.

## Conclusion

An extensive analysis of the H-ARAIM performance has been provided in this paper showing that ARAIM is robust to the loss of frequency and can provide 100 % availability for LNAV, RNP01 NM operation, US and EU ADS-B mandates in conservative assumptions for URA, Psat and Pconst. In nominal mode of operation based on optimal 24 + 24 satellites constellations, ARAIM can sustain HPL requirements of 20 m. It provides promising technical feasibility outcomes that may accommodate various aircraft implementation as the NSE will not be a driver. Those results open perspectives to a more relaxed ISM architecture that could lead to an increase in autonomy of the ARAIM integrity algorithm. This solution will definitely ease the implementation, standardization and certification process of a DFMC receiver using an ARAIM algorithm for horizontal based operations.

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## Disclaimer

The opinions expressed in this paper are those of the authors alone. This paper does not represent any formal positions of EUROCONTROL or the SESAR Joint Undertaking.

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[MSII]: Milestone II report, EU-U.S. Cooperation on Satellite Navigation Working Group C-ARAIM Technical Subgroup, February 2015

[PBN]: Performance Based Navigation Manual, ICAO, doc 9613 Vol II

[SPS]: Global Positioning System Standard Positioning Service Performance Standard, Department of Defense – GPS NAVSTAR, 4th edition – September 2008

# Innovations in boundary mapping

One of the objectives of the study was to develop a method for mapping customary land parcels using a UAV. A method was developed and tested in Namibia


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This study investigates the potential of using Unmanned Aerial Vehicles (UAV) in surveying and mapping customary land parcel boundaries. In Namibia, new laws demand for the boundaries of individual and collective customary lands to be adjudicated, mapped and recorded. Over two thirds of Namibia's population still live on unregistered customary land (Kasita, 2011). Thus, it has been the obligation of government to come up with developmental initiatives aimed at developing communal areas. One such initiative was the introduction of the Communal Land Reform Act No.5 of 2002 aimed at eliminating tenure insecurity in the communal areas.

Many studies relating to the use of UAV in land administration are emerging. These studies generally claim that UAV is now an alternative or supplement to conventional mapping techniques. Proven benefits with regards to costs, efficiency, accuracy and flexibility have been revealed, especially in urban areas where the majority of testing has been performed. However, the argument is yet to be empirically proven in more rural contexts, particularly those with customary lands. This study, therefore seeks to address this gap by testing the applicability of UAV technology in capturing images for surveying and mapping customary land rights.

Based on a joint publication by the FIG and the World Bank, "75% of the world's population do not have access to formal systems to register and safeguard their land rights and, therefore, there is an urgent need to build affordable and sustainable systems to identify the way land is occupied and used"(FIG & WORLD BANK, 2014). It is believed that the advancement in emerging technology such as small and affordable UAV systems and geo-information techniques offer an innovative means to capturing and producing cheaper and faster spatial data for use in land administration projects(Kelm, 2014). Such advancement in technology can help land administration agencies and governments to secure land rights for their people.

As Williamson, Enemark, Wallace, & Rajabifard, (2010) point out, emerging land administration systems do not require formal land surveying and mapping practices. The communal land registration system in Namibia is one such system. This means that there is no need for a professional land surveyor, as any technical employee with basic training can undertake the mapping exercise. In addition, the demarcation of physical boundaries is not required by law, but in order to reduce boundary conflicts and to have a graphical representation of the land parcel in the cadastre, a means to spatially identify land parcels and interests in land is required.

Studies in Namibia have revealed that aerial photos are the most efficient means to map customary land boundaries. However, since the beginning of the land registration program in 2005, aerial photos have not been available country wide. Until early 2014, the use of orthophotos has been limited to the northern part of the country due to high acquisition costs and prioritization as the major reasons behind the lack of or delayed acquisition of the aerial images. In addition, due to the amount of time it takes for the suppliers to prepare the images, they are out-dated at the time of delivery; this means that the images do not represent the current situation on the ground.

There has been on-going debate about the credibility of the mapping techniques used on communal land. Land surveyors

*The paper was presented at the "2015 World Bank Conference on Land and Poverty" The World Bank - Washington DC, March 23-27, 2015. Reprinted with permission*

in Namibia have not been in support of the use of hand held GPS and aerial photos, citing that the methods are not up to the prescribed standards set out in the law in terms of accuracy. This situation has threatened the envisaged merger of the Namibia Communal Administration System (NCLAS) with the Deeds system in the future.

This paper will present a general background of UAVs and their use in cadastral surveying. This will be followed by a discussion on the developed methodology for mapping customary land parcels with UAVs, which includes a look into the legal implications and the results of the pilot study.

## Study area

The study took place in the "Freedom Square" informal settlement situated on the outskirts of Gobabis Namibia. The settlement has approximately 3188 inhabitants in 808 households, the housing structures are made of corrugated iron sheets, plastic, grass and wood. The area was chosen because it gives a broad overview of the diverse spatial and social structures in different communal parts of the country. Furthermore, the area is close to the main town of Gobabis. Gobabis is the regional capital of the Omaheke region, located 200km east of the capital Windhoek, along the Trans Kalahari highway towards Botswana (22°00′S 19°30′E). The Omaheke region is one of the 14 regions in Namibia; it lies on the eastern border of Namibia. The close proximity of the area would accord the researcher more time to sensitize communities prior to flight, to process the data and return to communities to complete the mapping exercise. In the end it took less time and effort to get much higher yield in terms of number of households and variety in development status and density. Figure 1 shows the location of the study area.

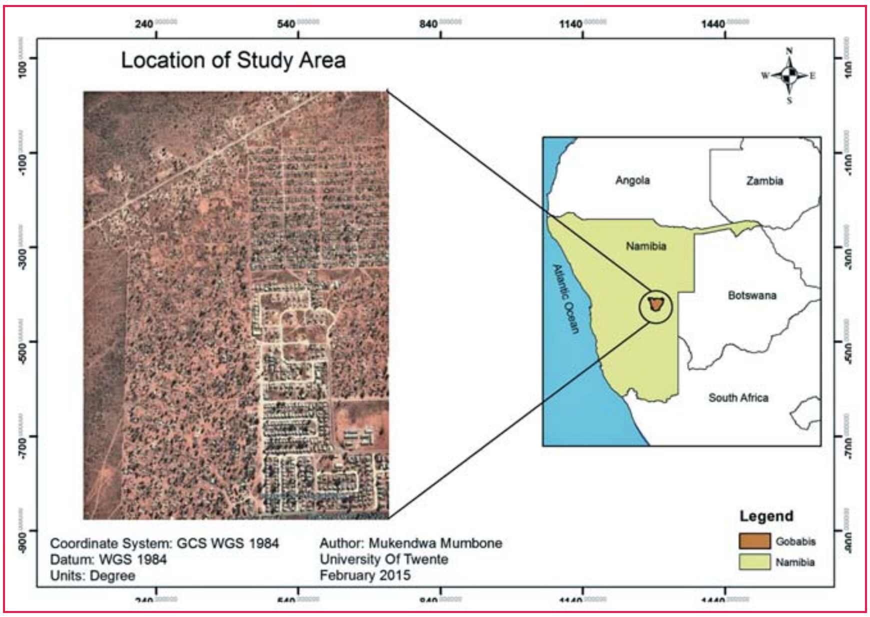


**Figure 1: Location of study Area**

## Background on UAV

Unmanned Aerial vehicles were initially designed for military operations, however recent advancement in technology have seen smaller, more lightweight platforms being used in civilian applications such as Forestry and Agriculture (Engel & Teichert, 2008), Heritage Management(Chiabrando, Nex, Piatti, & Rinaudo, 2011), Mapping and Surveying(Nex & Remondino, 2013). The term UAV photogrammetry has emerged (Eisenbeiss, 2009), which in simple terms is the use of UAV platforms for photogrammetric measurements. When used as mapping platforms, the platforms are equipped with photogrammetric measurement systems such as still or video cameras(Eisenbeiss, 2011).

Bailey, (2012) defined UAV as "a powered aircraft system that is remotely piloted, either manually or semi-autonomously by remote control or autonomously through the use of an on-board computer navigation system or a ground control station that sends commands wirelessly to the aircraft". Apart from the name UAV, various other names such as; Drone, UVS (Unmanned Vehicle System) and UAS (Unmanned Aircraft System) are commonly used. As argued by Eisenbei, (2009), UAS is commonly understood to refer to the whole system; the UA(Unmanned Aircraft) and the ground control station( GCs).

There are two distinct categories of UAVs, Rotary-wing and fixed-wing UAV systems. Rotary-wing is based on rotors and blades, and is said to be well suited for surveying small areas, whereas the fixed-wing's design is based on that of an aircraft and is suited for surveying larger areas (Tahar & Anuar, 2012). Furthermore, the multiple rotor design of the rotary-wing gives it the ability to fly steadily, hover over an area and capture images (Eisenbeiss & Sauerbier, 2011). According to Tahar & Ahmad, (2013), this gives the rotary-wing the ability to be more stable and thus capture images easily.

Both types may be used in land administration projects, depending on the scope of the project and extent of the area to be mapped. For example, mapping an entire village of up to 100ha would require a fixed wing, whereas mapping selected homesteads in that village would require the use of a rotary-wing UAV. In a UAV test in Switzerland, Manyoky et al. (2011) used the Octocopter Falcon 8 rotary wing UAV to capture images and demonstrated that UAV could reach the required accuracy for cadastral surveying.

In a study by Jing (2011), who investigated the application of UAVs in adjudicating land rights in a city in China, it was concluded that UAV technology can benefit adjudication in rural areas where accuracy standards are not high. Meanwhile Barnes et al. (2013) developed a methodology that entails the steps involved in using UAV for cadastral surveying and mapping projects. This was done on a case study basis in Albania. A similar workflow can be seen in (Eisenbeiss, 2011). In Albania (Kelm, 2014), UAVs were tested in three major areas; Rural mapping applications, Urban mapping applications and Peri-urban applications. In the rural area, it was tested whether the technology can deliver high resolution orthophotos that can be used for cadastral surveying. An orthophoto with 2cm accuracy was produced. The Albanian tests concluded that UAV technology is indeed fit-for purpose because it includes elements of flexibility, participation, inclusivity, affordability, reliability and upgradeability.

## Current process for mapping customary land parcels

To support the graphical part of the Namibia Communal Land Administration System (NCLAS), parcel boundaries need to be established. The most convenient and affordable means is the use of Orthophoto. As pointed out in a report by the Millennium Challenge Account (MCA, 2010), orthophotos were acquired in 2008, and are available digitally. They are geo-referenced 10x10 km tiles with a ground resolution of 1 meter and an accuracy of 2-3 meters.

This process begins with the retrieval of tiles that cover the area to be mapped. Tiles are printed and stored as hard copy. The tiles are carried along in the field where parcel owners identify their parcel boundaries and mark them with a fine pointed marker pen. Sometimes this is done house to house, or in cases where a prior arrangement had been done, a community meeting is arranged. Back in the office, the tiles are scanned and the parcels vectorised. The problem with this approach is that the orthophtos are out-dated. The orthophotos are over 8 years old, and do not depict developments that have taken place over the eight years. In addition, the printing and scanning of orthophotos causes them to lose accuracy.

Alternatively, the use of GPS is employed. This system includes simple hand-held GPS devices with an accuracy of about 5-10 meters, and cost between N$ 500 – N$ 2000(€50-200) per unit. A GPS survey can map up to an average of 10 land parcels a day depending on the size.

The process begins with the preparation of the GPS equipment. The GPS receivers are set up to WGS84 datum, and further set up to collect waypoints in Decimal Degrees. Parcels are then marked by walking to each parcel corner and marking the way point at that specific corner. The way point numbers for each parcel are recorded on a paper (data collection sheet) as back up. After completion, the way points are downloaded on to a computer as shapefile (.shp). Making reference to the data collection sheet, the waypoints are connected to each other creating polygons. Each polygon is given the owner's name and a unique parcel identifier (UPI).

## Mapping customary land parcels with UAV in Namibia

### Legal implications

Despite the laws demanding for customary land parcels to be mapped and adjudicated in Namibia, surveying methods are not prescribed. This study uncovered that the Communal Land Reform Act #5 of 2002 does not specify the type of survey instruments or the minimum accuracy standards that should be considered in mapping customary land parcels.

The land survey act 33 of 1993 specifies classes of surveys, and accuracy standards, but nothing specific is said about communal land. Class A for urban areas, Class B for surveys in townships, and Class C for "all other surveys not included in class A and B". It is also stipulated under the same regulation that the Surveyor General may determine the standard of accuracy of any survey operation that is not specified in the regulations. There is however no documentary evidence that the Surveyor General has ever determined any surveying standards for communal lands.

There researcher therefore, found this to be vague and misleading as there is no reference of communal land falling under any of the mentioned classes. This vagueness in the law leaves land administrators with the task of being proactive and constantly research and employ new methods and techniques that are fit for purpose. In the case of UAVS, research has shown that UAV use is heavily regulated in most countries. In the case of Namibia, this study reveals that there are regulations put in place for using the UAVs. The regulations do not prevent the use of UAVs for mapping applications or any other applications.

The Namibia civil aviation authority (Aviation act 74 of 1962) compels any person who would like operate a "remotely piloted aircraft", which in this study is understood as a UAV, to seek prior approval from the relevant authorities. UAVs may not be operated within a published controlled zone,

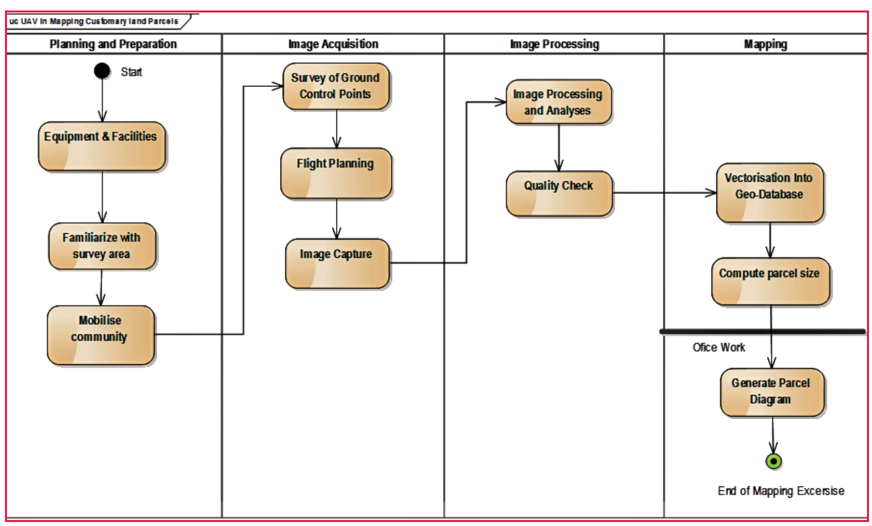


Figure 2: Methodology for mapping Customary Land Parcel's with UAV

air traffic zone or air traffic area. The maximum flight height cited is 45.7m/ 150 feet, and this should not be closer than 5 nautical miles to an airport.

These finding brought the researcher to the conclusion that, since there are no tools and techniques prescribed by law, any survey and mapping method can be employed, given it has been proven to work. Therefore, these findings warrant for the testing of UAVs in mapping customary land parcels in Namibia.

## The pilot test

A methodology was developed in order to integrate UAVs in mapping customary land parcels. The methodology consists of four main sections; Planning and Preparation, Image Acquisition, Image processing and Mapping, as seen in figure 2. Different stages in each section are presented and discussed. To test the methodology, a pilot test was undertaken in the "Epako North" informal areas in Gobabis Namibia.

### Planning and preparation

This stage entails the planning and preparation of the project. The area to be mapped is studied; the equipment and facilities are prepared. According to (Barnes, Volkmann, Sherko, & Kelm, 2014)The following technical aspects are to be considered:

(i) The type of UAV platform- this is determined by the size of the area to be mapped, the larger the area is the more the need to use a Fixed wing UAV

(ii) GSD -This is an important consideration in a project; GSD depends on the required resolution. The higher the resolution, the smaller the GSD values. These require low flying height and slower speeds. For ultra-high resolution needs, the use of rotary wing UAVs is recommended.

(iii) Nature of Terrain- This affects the choice of UAV platform to use. Fixed-wing UAVs may require an open flat surfaced area for launch and landing, whereas rotary wing is easier to launch in a dense forest area or built up area.

(iv) Regulatory limitations- it is important to consider the legal regulations before flying.

**Figure 3: Fixed-Wing UAV**

For this study, a locally manufactured fixed-wing UAV (figure 3) was used to capture the Imagery for the study area "Epako North" which covers an area of 160 ha/ 1.6km2. The drone used has a payload of 650g and was fitted with a 16mp camera from Sony.

### Image acquisition

Image acquisition involves the acquisition of ground control points, mission planning and the launching of the flight. The acquisition of ground control points is dependent on whether or not geo-referencing of the end product (orthophoto) is required. In case there is a need to fulfill specific accuracy standards, geo-referencing is required, and hence ground control points need to be collected. Ground control points are usually surveyed with the use of high accuracy differential GNSS equipment, and placing markers systematically across the area.

The markers are usually bright colored features that are easily visible in an image. Once the ground control points have been surveyed, a flight mission is then developed. This can be done using open source flight planning software which is freely available on the web. In mission planning, the desired area is marked on an image from Google Earth; together with other parameters, this guides the UAV in its mission.

For this study, a total of 23 ground control points where placed systematically across the area, using V-maps differential GPS system. The V-Map system is a pair of light weight (130g) dual frequency receivers small and light enough to be carried by small drones (Figure 4). The units are configured for event marking and are primarily designed to determine camera exposure positions by means of post-processing L1 and L2 phase observations. To locate a known reference point, coordinates were sourced from a land surveyor who had previously surveyed the area. These coordinates were loaded into a GPS navigating device with the aim of locating at least one of the points.


**Figure 4: V-map GPS system (http://www.microaerialprojects.com/v-map/)**

This activity however proved futile as the markers had either been removed or buried deep in the sand. To remedy this situation, a local reference point was established and a local reference station was installed and positioned through GPS (WGS 84 Datum). It is important to note that because of the remaining, unknown offset with the mapping frame, the coordinates of the GCPs also have this unknown bias. Manholes, tires and white paper plates stuck in the ground were used as markers.

The excess amount of ground control points were a guarantee that in the end of the flight, some GCPS would still be visible besides being removed by children or blown away by the wind. Otherwise, only 17 of them were used; 12 control points for geo-referencing and 5 check points for validation. The coordinates where established using post–processing techniques because the GPS system was not in Real Time Kinetic (RTK). Whether in practice such a large number of ground control points is necessary is subject to further research. In this study we wanted to ensure highest available accuracy.

**Table 1: Accuracy assessment from Pix4DMapper**

| **GCP Name** | **Accuracy XY/Z [m]** | **Error X [m]** | **Error Y [m]** | **Error Z [m]** | **Projection Error [pixel]** | **Verified/ Marked** |
|---|---|---|---|---|---|---|
| 2356 (3D) | 0.020/0.020 | 0.021 | 0.016 | -0.003 | 0.164 | 9/9 |
| 2381 (3D) | 0.020/0.020 | 0.088 | -0.059 | -0.137 | 1.707 | 6/6 |
| 2382 (3D) | 0.020/0.020 | 0.039 | -0.010 | -0.027 | 0.220 | 13/13 |
| 2384 (3D) | 0.020/0.020 | -0.003 | 0.006 | -0.072 | 0.049 | 3/3 |
| 2404 (3D) | 0.020/0.020 | 0.034 | -0.038 | 0.004 | 0.685 | 10/10 |
| 2408 (3D) | 0.020/0.020 | 0.008 | 0.033 | 0.071 | 1.799 | 14/14 |
| 2409 (3D) | 0.020/0.020 | -0.003 | 0.017 | -0.032 | 0.732 | 11/11 |
| 2410 (3D) | 0.020/0.020 | -0.019 | 0.009 | 0.023 | 0.480 | 13/13 |
| 2411 (3D) | 0.020/0.020 | -0.017 | -0.029 | -0.103 | 0.425 | 3/3 |
| 2414 (3D) | 0.020/0.020 | -0.041 | 0.003 | -0.025 | 0.578 | 8/8 |
| 2416 (3D) | 0.020/0.020 | -0.016 | 0.013 | 0.049 | 0.504 | 3/3 |
| 2418 (3D) | 0.020/0.020 | -0.018 | -0.031 | -0.003 | 1.126 | 15/15 |
| **Mean** | | 0.006123 | -0.005900 | -0.021293 | | |
| **Sigma** | | 0.033471 | 0.026253 | 0.057343 | | |
| **RMS Error** | | 0.034026 | 0.026908 | 0.061168 | | |
| 0 out of 5 check points have been labeled as inaccurate | | | | | | |
| Check Point Name | Accuracy XY/Z [m] | Error X [m] | Error Y [m] | Error Z [m] | Projection Error [pixel] | Verified/ Marked |
| 2405 | 0.0200/0.0200 | 0.0941 | 0.0354 | 0.2332 | 0.8530 | 12/12 |
| 2406 | 0.0200/0.0200 | 0.0340 | 0.0771 | 0.2951 | 0.5718 | 12/12 |
| 2407 | 0.0200/0.0200 | 0.0450 | 0.0457 | 0.2231 | 0.9761 | 12/12 |
| 2412 | 0.0200/0.0200 | -0.0121 | -0.0169 | 0.1624 | 0.5234 | 13/13 |
| 2415 | 0.0200/0.0200 | -0.0545 | 0.1517 | -0.0759 | 0.5443 | 14/14 |
| **Mean** | | 0.021302 | 0.058591 | 0.167582 | | |
| **Sigma** | | 0.050772 | 0.055533 | 0.128803 | | |
| **RMS Error** | | 0.055060 | 0.080727 | 0.211362 | | |

In order to be able to later assign the right coordinates to the correct ground control point, each time a ground control point was established, its positions was fixed by placing and leveling the rover over it for 60 seconds, during which a photograph was taken at 30 seconds on each point with a camera whose time is synchronized with that of the GPS. Using the open source planning software called "Mission Planner" a flight plan was designed to cover the study area with an average ground sampling distance (GSD) of 45mm. The flight plan was uploaded to the UAV system, which was then launched to capture 16MP images with the following specifications: 150m flight height and an average air speed of 14m/s, a lateral overlap of 70%, and forward overlap of 80%.

## Image processing & quality check

This stage involves the orthophoto generation and quality check. The generation of the orthophoto is achieved through various photogrammetric operations. Firstly, camera calibration is performed, which is followed by the processing of the images to create 3D point clouds. The point cloud is then geo-located using ground control points that have been identified in the image. The point cloud is then used to generate a Digital Surface Model (DSM). The geo-referenced images are combined to form an Orthomosaic. There is a number of image processing software available. Once this is done, it is good practice to perform a quality check of the orthophoto in terms of accuracy.

In this study, the image processing was carried out using professional software called "Pix4DMapper" from Pix4D. The interior orientation parameters of the camera (focal length, position of the principal point, and lens distortion parameters) were estimated through a self-calibration process, i.e. during bundle block adjustment. An alternative pre-calibration was not possible in the field and experience shows that self-calibration delivers sufficient accuracy for most applications. After bundle block adjustment, photogrammetric results such as a Digital Surface Model and an Ortho-mosaic were generated.

The next stage in the methodology is the quality check. This was the assessment of the photogrammetric result in terms of accuracy. During initial processing by pix4dmapper, an accuracy assessment report for the bundle adjustment was generated. The result shows an average ground sampling distance (GSD) of 4.81cm. Table 1 shows the results of the accuracy assessment using object coordinate residuals at both ground control and check points based on Root Mean Square error (RMSE). It should be noted that the accuracy considered is that of the check points (bottom), because check points are independent from bundle adjustment.

Table 2: Accuracy for checking quality of Orthophoto

| | Ground Truth | | Measured | | Residuals | |
|---|---|---|---|---|---|---|
| **NO** | **X** | **Y** | **X** | **Y** | **ΔX** | **ΔY** |
| **2356** | 292074.017 | 7517955.636 | 292073.987 | 7517955.658 | 0.030 | -0.022 |
| **2381** | 292381.075 | 7518073.440 | 292381.072 | 7518073.467 | 0.003 | -0.027 |
| **2382** | 292188.984 | 7518096.376 | 292188.963 | 7518096.382 | 0.021 | -0.006 |
| **2384** | 291779.120 | 7518387.443 | 291779.133 | 7518387.419 | -0.013 | 0.024 |
| **2404** | 292514.386 | 7518250.864 | 292514.332 | 7518250.935 | 0.054 | -0.071 |
| **2408** | 292048.232 | 7518270.925 | 292048.207 | 7518270.954 | 0.025 | -0.029 |
| **2409** | 292042.929 | 7518335.936 | 292042.947 | 7518335.923 | -0.018 | 0.013 |
| **2410** | 292112.304 | 7518376.290 | 292112.322 | 7518376.273 | -0.018 | 0.017 |
| **2411** | 292186.200 | 7518428.156 | 292186.233 | 7518428.171 | -0.033 | -0.015 |
| **2414** | 292263.293 | 7518707.092 | 292263.379 | 7518707.038 | -0.086 | 0.054 |
| **2416** | 292717.935 | 7518945.086 | 292717.955 | 7518945.003 | -0.020 | 0.083 |
| **2418** | 292886.743 | 7518522.505 | 292886.644 | 7518522.466 | 0.099 | 0.039 |
| | | | | **RMSE** | **0.045** | **0.040** |
| | **Ground Truth** | | **Measured** | | **Residuals** | |
| **NO** | **X** | **Y** | **X** | **Y** | **ΔX** | **ΔY** |
| **2405** | 292521.693 | 7518336.259 | 292521.697 | 7518336.245 | -0.004 | 0.014 |
| **2406** | 292489.554 | 7518352.497 | 292489.486 | 7518352.436 | 0.068 | 0.061 |
| **2407** | 292520.834 | 7518400.965 | 292520.829 | 7518400.885 | 0.005 | 0.080 |
| **2412** | 292265.044 | 7518471.970 | 292265.055 | 7518471.967 | -0.011 | 0.003 |
| **2413** | 292399.022 | 7518557.041 | 292399.053 | 7518555.928 | -0.031 | 1.113 |
| **2415** | 292489.894 | 7518609.267 | 292489.970 | 7518609.121 | -0.076 | 0.146 |
| | | | | **RMSE** | **0.044** | **0.460** |

The error in X (east) is 5 cm whereas in Y (north) is 8 cm. From these results, it can be concluded that UAV techniques that are used in this study gives very high accuracy on 2D mapping. In the same table, it can be seen that there is a 21cm error in height. However, considering the fact that the maps used for cadastral purposes require just X and Y coordinates, Z coordinates and their accuracy do not play a significant role on mapping and on 2D cadastre in general. Thus, for this study height was not considered.

To evaluate the quality of the orthophoto, further analyses were done. GCPs were uploaded into Arcmap, where the base layer was the generated orthophoto. A manual approach was applied where the researcher visually checked if the uploaded coordinates of the ground control points fits with their marker on the orthophoto. In cases where there were significant differences (mostly in cm), the researcher then manually retrieved the coordinates from the center of the mark which is visually represented in the orthophoto.

An assumption was made to use the GCPs collected in the field by GPS as the reference value to use in comparison with the coordinates retrieved from the orthophoto in arcmap. The Root Mean Square Error (RMSE) of the coordinates was then computed in Microsoft Excel (Table 2).

It can be seen in table 2 that the accuracy of the orthophoto is 4cm in X and 5 cm in Y, which is not significantly different from the Pix4d generated accuracy (Table 1). We can also observe that the residual delta Y in point 2413 is significantly different to other points. This error could have been caused by a wrong measurement or it is an outlier. A conclusion can therefore be drawn that the intermediate steps (image matching, terrain modeling, and orthophoto projection) did not significantly reduce the accuracy of the final orthophoto; hence we can assume that point on ground, measured within this orthophoto will have a positional accuracy with a standard deviation of 4 to 5 cm.

## Mapping

The final part in the methodology is mapping, which includes vectorisation, computing of the parcel boundary and the generation of the parcel diagram. Vectorisation refers to the process of converting raster data into vector data. In this case, land parcel boundaries are traced on the image (raster) and stored into a geo-database as vector polygons. The parcel size is computed in Arcmap and displayed on the parcel diagram. The parcel diagram is the final output of this exercise.

This activity took place after the image processing and quality checks were completed. A meeting was held with a small number of people from the community in the study area. During the meeting, a laptop was used to view the orthophoto digitally in Arc Map, and each of the people took turns to identify their parcel boundaries on the image. The researcher then vectorised the parcels and immediately entered the parcel information in the attribute table. The vectorised parcels can be seen in figure 5 and 6. Each parcel was given a unique parcel identifier (UPI). The UPI is a unique id associated to each parcel of land and linked to the name of the parcel owner in the database.


Figure 5: Zoomed Image showing Mapped Parcels

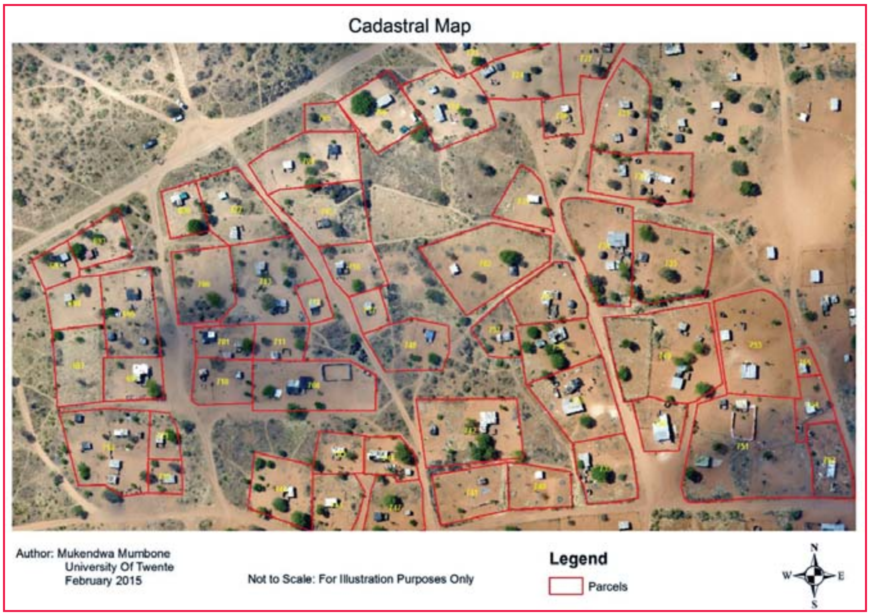


Figure 6: Image showing Mapped Parcels

A line is simply drawn around the holder's land parcel guided by natural features such rows of trees, hedges and rocks, or man-made features such as fences, foot paths and roads. Since the guiding features were clearly visible on the images, it can be concluded that in addition to good spatial accuracy, the orthophoto also delivers good visual quality. Thus, it can be argued that UAV generated orthophoto is well suited for mapping customary land parcels.

Barnes, Volkmann, & Barthel, (2013) advocate for the use of unmanned aerial vehicle in the "In-situ" delivery of high resolution aerial photos, as well as promotion of citizen participation in adjudication. This exercise saw a number of people, including the elderly participate in the mapping process. Participation by all land owners and their neighbors prevents or minimizes boundary disputes because all concerned parties are involved in the mapping process. This affirms that UAV-mapping encourages participation.

## Conclusion

This study concludes that the UAV enabled mapping approach enables capture of high resolution images out of which good quality orthophotos can easily be generated. Due to the high resolution nature and timeliness, such images can easily be used for mapping customary land rights boundaries; this can be done in a fast and relatively cheap fashion of vectorising parcels straight on-screen, without having to print the orthophoto. This exercise also proved that the visual quality of the images is adequate for boundary mapping as the guiding features such as fences and hedges were clearly visible.

This study further revealed that the accuracy derived from photogrammetric operations is good enough to fit the purpose of mapping customary land parcels. The accuracy assessment was done in order to test the degree of error produced by the proposed UAV method. It was revealed that accuracy derived from this method surpasses those derived from hand held GPS receivers and the current orthophotos. The results show an accuracy of 4-5centimeters, which is by far higher than that of current methods (5-10meters).

With these accuracy results, this study recommends for further studies into the potential merger of the communal cadaster into the country's main deeds system. It is further recommended that the use of UAV be considered in other similar applications in Namibia i.e; farm assessments and monitoring activities, building of 3D cadastre in urban areas, and informal settlement planning and upgrading. It is also important to study whether these approaches can be transferred to other countries with specific land administration needs.

There are many other ways to verify the accuracy of an orthophoto. However, due to time limitations such avenues were not explored in this study. Should there be a need to verify these results, this study recommends that other evaluations methods be used; for example, to perform a ground survey using RTK GNSS, and then compare with the accuracy of the vectorised features. This however depends on the quality needs of the survey as it is time consuming and may lead to extra costs.

Costs are an important consideration in land administration projects. However, costs were not in the scope of this study, but it is recommended that a comprehensive cost-benefit analysis study be undertaken when considering the adoption of the technology.

Given that this study aimed to ensure highest possible accuracy, many ground control points were collected, which time was consuming. Further studies are encouraged to find out whether in practice such a large number of ground control points are necessary. There are already UAVs on the market with a dual frequency RTK receiver, see e.g the system Sirius Pro by Mavinci (http://www.mavinci.de/en/siriuspro), which means that the location of the camera for each single image can be theoretically computed by 2-4 cm accuracy. Further research should show whether such a system can be used to further reduce the number of ground control. A similar product can be seen in (ELING, 2014; Rieke & Foerster, 2011).

The study also revealed that laws are vague with regard to surveying methods and techniques on communal land. Therefore, it is recommended that laws be reviewed accordingly, and necessary amendments be made. This will prevent speculation.

Results generated in this study show that the developed methodology is functional. Thus, it is recommended that this methodology be explored further in a sanctioned communal land registration exercise by the Ministry of Lands and resettlement.

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# Coordinates

## Indian cities are changing... For worse?


mycoordinates.org/vol-1-issue-3-august-05/

### Physical information inputs for planning agencies

Proposed Design of technology-mix based on GPS and Photogrammetry

Prof P Misra

It is very evident that all the required information need not be built as one project. The urban database can be designed on the 'evolved' basis. The priority information needed by most of the users can be collected first. The remaining information and attributes can be acquired in the phased manner. The direction of thinking has led us to first create the essential information through proper aerial photography, field surveys for ground controls and Photogrammetry which will act as foundation to link any other spatial information to be collected in subsequent phases. As a word of caution, the control technology in the field should be very reliable and accurate right from the beginning.

Mainstream Disaster Management

### Another wake-up call

Shveta Mathur and Anshu Sharma

The answer to Mumbai's woes, and those of many cities like it, lies in mainstreaming disaster management in development planning. The environment needs to be given some space in our cities. Politicians need to be stopped from converting green buffers into paved real estate that reduces ground percolation and increases surface runoff. Landuse plans, network and service plans, transport plans and civic infrastructure management plans, all need to take into account the critical factors of environmental carrying capacities of cities, and incorporate risk reduction measures as well as emergency response mechanisms. Unless this is done, we will continue writing and rewriting obituaries of our disaster management plans.

Mumbai floods

### How GPS-GIS can help

The Mumbai floods have again highlighted the importance of disaster management using modern technology

Prof Madhav N Kulkarni

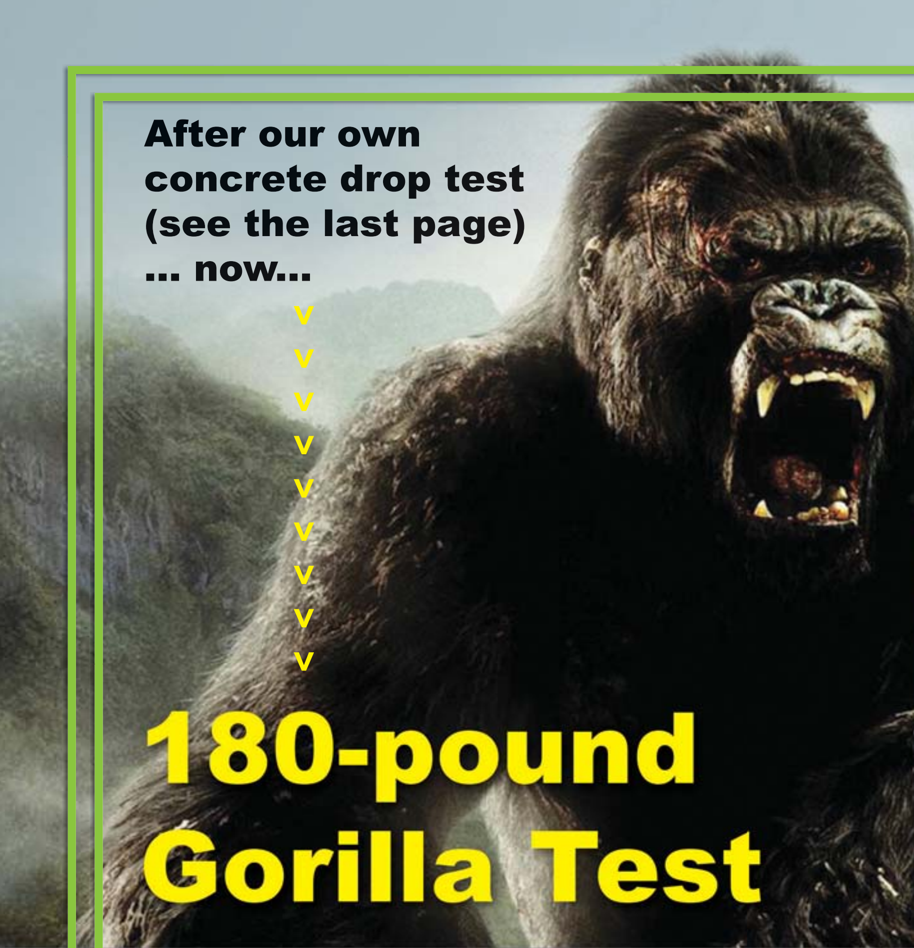
In conclusion, an integrated approach to include input from several diverse techniques is a must for understanding, monitoring and managing the various natural and man-made disasters. It is essential that coordination at all levels must be ensured to facilitate smooth functioning of the entire system, easy data exchange, and scientific cooperation. Frequent meetings of the agencies involved in the work, and close monitoring are essential for this purpose. It is important that latest digital map data on largest possible scale, and GPS-GIS integrated positioning systems are made available to the disaster management teams, for effective rescue and rehabilitation operations.

### When ellipsoidal heights will do the job, then why not use them!

The paper explains and provides important details "where and how" the ellipsoidal height will work. It also includes algorithm(s) or procedural steps to get the best results in using ellipsoidal heights or depths.

Muneendra Kumar, Ph.D.

In topographic mapping, charting, navigation, vertical crustal movement monitoring, and other non-engineering applications, direct use of GPS surveyed accurate ellipsoidal heights will provide a practical, cost effective, and time saving approach. In case of vertical movement monitoring, any change in definition or the software can contaminate the data integrity.



**After our own concrete drop test (see the last page) ... now...**

v
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# 180-pound Gorilla Test

I had a shovel and metal detector in my left hand, and the LS on a carbon fiber pole in my right hand. I have no idea what tripped me as I stepped from the woods, and onto an **old gravel covered asphalt** parking lot. This did not simply fall to the ground, it had **180 pounds of surveyor driving it into the pavement**. It was not a straight fall, I kind of slid across the pavement. The scratch on the top right area of the screen is from a rock.

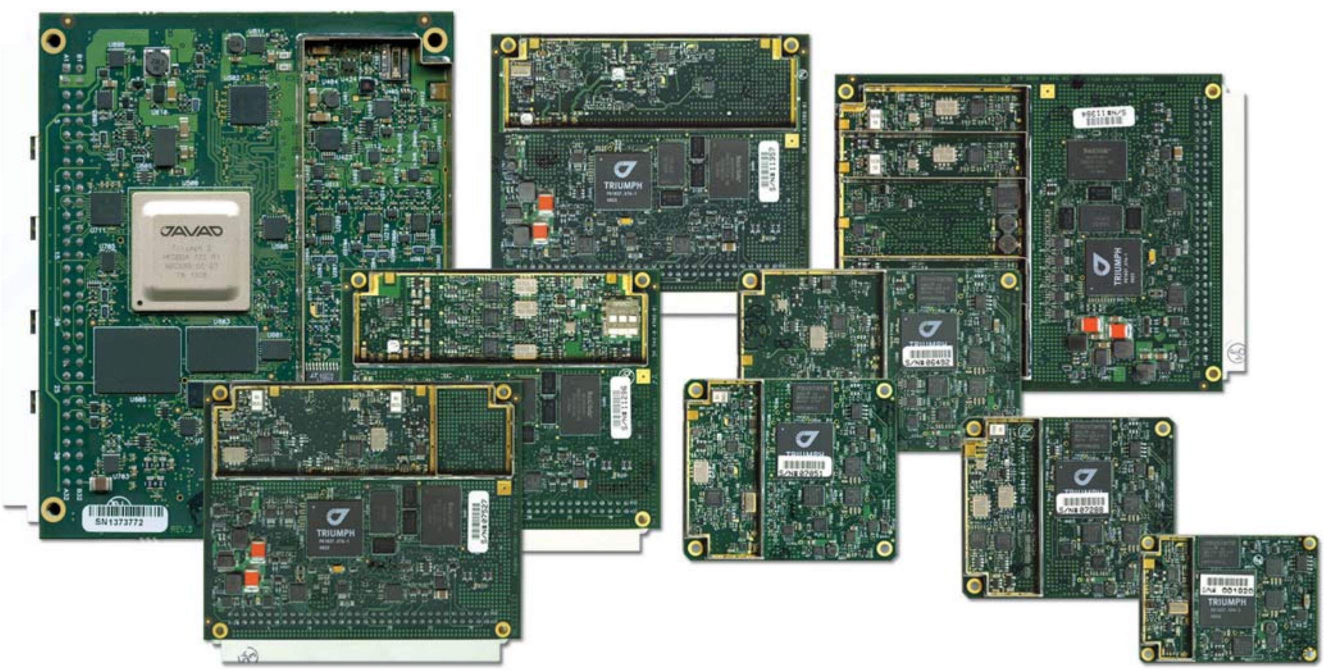

At first it would not turn on. After I picked all of the rocks and broken glass from the holes that used to be buttons, I pressed the power button, and it came to life. I had no problem performing a full archive, and an active project archive, as well an export of the job I was working on. So no data lost. As can be seen in the photos...it still works fine.

Possibly a little wipe with a magic paper towel, and some Windex, and it will look like new??

John Evers, PLS

# Antennas


# OEM Boards

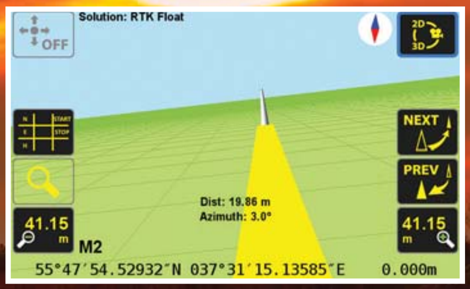


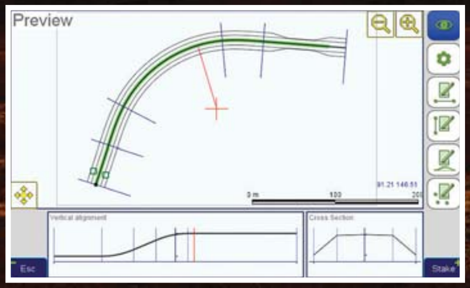
A variety of high performance GNSS OEM boards.

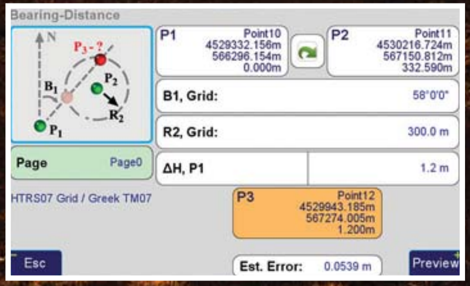
# TRIUMPH-LS

## Receiver+Antenna+Radio Modem+Controller+Pole


- **864 Channels for all GNSS signals**
- **24 Hours Battery Life**
- **Interference monitoring of all GNSS and UHF channels**
- **Visual Stake out**
- **Lift & Tilt**
- **6 parallel RTK engines**



# TRIUMPH-1M

## GPS + GLONASS + Galileo + BeiDou + QZSS

TRIUMPH-1M has same features as TRIUMPH-LS but without integrated controller.

TRIUMPH-1M and Victor-LS make a complete RTK system.


TRIUMPH-1M + Victor-LS

# TRIUMPH-2

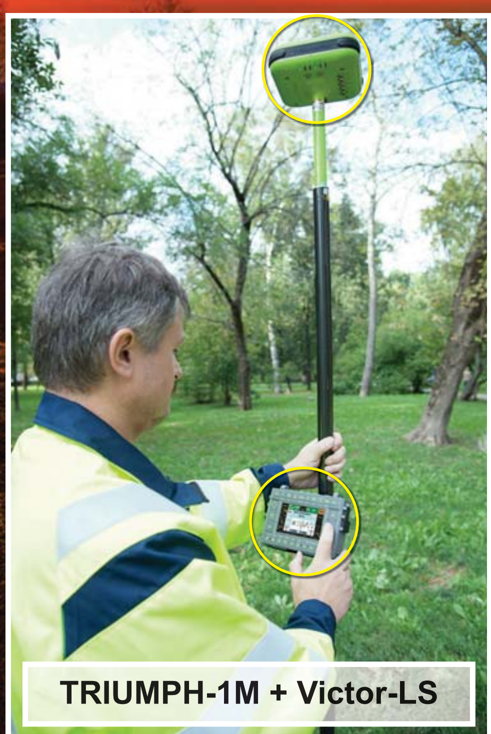
Static → GLONASS → RTK Base → RTK Rover


TRIUMPH-2 tracks GPS L1/L2,
GLONASS L1/L2 and Galileo L1.

# Victor-LS

## The Rugged Field Controller


Victor-LS is a rugged field controller. It runs J-Field and can be used with TRIUMPH-1 and TRIUMPH-2.



TRIUMPH-1M + Victor-LS

TRIUMPH-2 + Victor-LS

# The one and the only Digital Radio Transceiver in the world!

Unique adaptive digital signal processing, which has benefits: the full UHF frequency range and all channel bandwidths worldwide • the best sensitivity, dynamic range, and the highest radio link data throughput • embedded interference scanner and analyzer • compatibility with another protocols
Cable free Bluetooth connectivity with GNSS receivers and Internet RTN/VRS access via embedded LAN, Wi-Fi, and 3.5G

And all this with competitive prices!

### HPT435BT/HPT135BT/HPT225BT*

**$2,710**

35 W UHF/VHF Transceiver

### HPT404BT/HPT104BT/HPT204BT*

**$1,640**

4 W UHF/VHF Transceiver

### HPT401BT/HPT101BT/HPT201BT*

**$2,040**

1 W UHF/VHF with internal battery

### L-Band/Beacon

**$1,550**

Receivers for multiple applications

### ISM Radio

**$840**

CEPT 868-870 MHz, FHSS 902-928 MHz

### OEM Solutions

**$840**

902-928, 360-470, 225-255, 138-174 MHz

### JLink 3G*

**$2,375**

Web-interface Wi-Fi, Ethernet, 3.5 G, UHF/VHF/FH915

### JLink 3G BAT*

**$2,735**

Web-interface Wi-Fi, Ethernet, 3.5 G, UHF/VHF/FH915, internal battery

*Power, data cables and antenna are included.

# Drop Test

See video at **www.javad.com**

# Determination of surface characteristics and alteration of Koru mining area by UAV photogrammetry

In this study, a low-cost UAV-based remote sensing approach reveals high-resolution digital surface models has been utilized for surface characterization

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## Introduction

### Study Area

The study area is located near the Koru (Lapseki/Çanakkale) village in northeastern part of the Biga Peninsula. Koru deposit is hosted by volcanic rocks which are directly related to economically significant mineralization such as Pb-Zn. This deposit is shaped by Tertiary volcanic units, including rhyolitic lava and tuffs.

### UAV-based Remote Sensing for Geological Classification

Many scientists have performed UAV-based photogrammetry and remote sensing for many decades. As the first motorized UAV photogrammetry workings, fixed wing remote controlled air vehicles have been developed in 1970s (Przybilla and Wester-Ebbinghhaus, 1979). The first high-resolution digital elevation models was produced by Eisenbeiss et al. (2005) using autonomously UAV helicopter. Nowadays, there are many other UAV-systems for using (Jütte, 2008, Gomez-Lahoz and Gonzalez-Aguilera, 2009, Fotinopoulos, 2004, Aber et al., 2002). The use of high resolution digital photogrammetry based on UAV technology for classifying of surface geology has been tested in this study.


Figure 1: Studying Area

## UAV SYSTEM

### Eight-Rotor Oktokopter UAV

When compared to conventional helicopters, quad-rotor systems are more stable in flight with reduced vibration and have the mechanical advantage of not requiring a large, variable pitch rotor-unit. Our in-house developed quad-rotor system is stabilized by inertial measurement units (IMU), including three acceleration sensors, three gyroscopes, a three-axis compass, pressure sensor, and is regulated by basic PID (proportional integral differential) loops. A quad-rotor open source project (Mikrokopter, 2009) has been used and improved by modifications of the software and the electronic circuit, in order to comply with the requirements for landslide studies. Technical data of Oktokopter XL can be summarized as follows:

- Dimensions 73x73x36 (BxLxH)
- Payload: recommended max. payload = 2,500 g
- Max. altitude: Line of sight (several 100 m)
- Max. distance: Line of sight (several 100 m)
- Flight time: max. 45 min at full battery load (30 Ah)

**Figure 2: UAV Okto XL Mikrokopter Full Ready to Fly**

- Realistic flight time: 18-28 Min (10 Ah) [See tables below]
- Telemetry with speech: Voltage, capacity, current, altitude, distance, direction, speed and temperature

### Camera-systems

For optimum flight time, the eight-rotor UAVs should be equipped with lightweight low-cost digital compact camera, which support manual camera settings. In this study, we used Canon EOS-M Mirrorless Digital Camera (see Figure 3). For all flights, the camera settings were fixed to ISO 200 at F2.8 and a focus of 18 mm. These settings enabled an average shutter speed of 1/800s which was necessary to avoid blurred photographs.

Specifications:

- Type: Digital single-lens non-reflex, AF/AE camera
- Image Format: 22.3 x 14.9 mm (APS-C size)
- Compatible Lenses: Canon EF-M lenses, Canon EF lenses including EF-S lenses (35mm-equivalent focal length is approx.,1.6x the lens focal length)
- Lens Mount: Canon EF-M mount (Canon EF-M lenses can be mounted directly to the camera. Canon EF lenses (including EF-S lenses) can be attached by using the optional Mount Adapter EF-EOS M.)


**Figure 3: Canon EOS-M Mirrorless Digital Camera**

Lens System:

- Type: Wide-angle lens - 22 mm - F/2.0 STM Canon EF-M
- Focal Length Equivalent to 35mm Camera: 35 mm
- Focus Adjustment: Manual/Automatic
- Min Focus Range: 5.9 in
- Max View Angle: 63.5 degrees
- Lens Construction: 6 groups/ 7 elements
- Filter Size: 43 mm
- Lens System Mounting: Canon EF-M

## Camera calibration scheme

Camera calibration determines information about the camera that improves accuracy in subsequent studying projects. Calibration process calculates the camera's focal length, lens distortion, format aspect ratio, and principal point. The resulting calibration data file can be saved on disk for use in all the projects that involve photographs taken by that camera. High accuracy works, e.g., digital surface modeling, require a well calibrated camera. Various calibration algorithms have been developed and improved over a period of more than decades. Some automatic camera calibrators are fully automated and very accurate, plus they are included at no extra charge as part of the basic software package. It is designed to be practical to use and suitable for the broadest range of automatic camera calibrator users. In this study, we used PhotoModeler's camera calibrator. To do it, we have performed the field calibration project using calibration sheets including the coded targets (see Figure 4). The calibration status report is given in Figure 5.

## Image acquisition

A set of UAV-acquired photographs covering the whole mining area in Koru (Lapseki/Çanakkale) village were taken. The achievable altitude over ground was in the range between 40 m and 70 m. All photographs were taken manually using shooter of remote controller and First Person View (FPV) flying mode. In a first in-situ flight planning step, the desired area and suitable locations for starting and landing were chosen. Then the quadrotor was launched to the maximum flight altitude of about 70 m. At this location, the UAV was hovered for about 45 seconds. Note that the pilot initiated vertical landing. After each flight, we downloaded and checked the covered area of the acquired photographs on-site (see Figure 6).

## Digital surface model processing

In order to produce digital surface model, we processed the data in PhotoModeler Scanner software. The photographs of the entire mining area (manually pre-selected by criteria like image quality and covered area size) were computed to digital surface models in 4 sub-areas. First, all photographs were processed to get the image planes from the UAV photographs and camera positions [see Figures 7 (a) and (b)]. Then, these data were supplied to the patch based multi-view stereo procedure of the software that finally computed a dense point cloud for all supplied photographs.

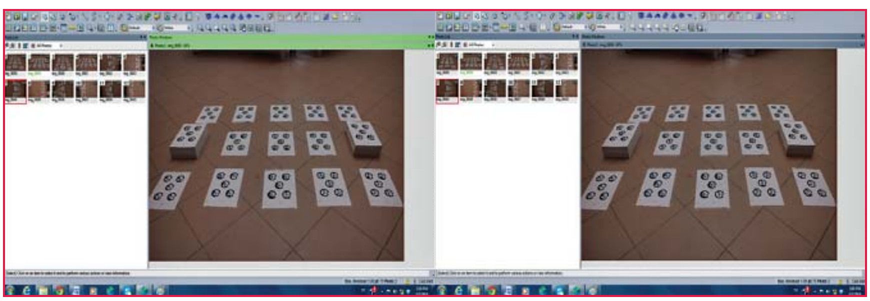

**Figure 4: Calibration processusing calibration sheets**

```
Status Report Tree
   Project Name: eosm_calibration.pmr
   Problems and Suggestions (1)
      Project Problems (1)
   Information from most recent processing
      Last Processing Attempt: Fri Feb 07 16:23:40 2014
PhotoModeler Version: 2014.0.0.1302 - final,full (64-bit)
      Status: successful
      Processing Options
         Orientation: on
            All photos oriented.
            Number of photos oriented: 12
         Global Optimization: on
         Calibration: on (full calibration)
         Constraints: off
      Total Error
         Number of Processing Iterations: 4
         Number of Processing Stages: 2
         First Error: 41.112
         Last Error: 4.548
      Precisions / Standard Deviations
         Camera Calibration Standard Deviations
            Camera1: Canon EOS M [18.00]
               Focal Length
                    Value: 18.697047 mm
                    Deviation: Focal: 0.003 mm
Xp - principal point x
                    Value: 11.632606 mm Deviation: Xp: 0.005 mm
Yp - principal point y
                    Value: 7.782084 mm  Deviation: Yp: 0.006 mm
Fw - format width
                    Value: 22.768255 mm Deviation: Fw: 0.003 mm
Fh - format height
                    Value: 15.163800 mm
               K1 - radial distortion 1
                    Value: 4.947e-004   Deviation: K1: 3.9e-006
               K2 - radial distortion 2
                    Value: -8.669e-007  Deviation: K2: 2.9e-008
               K3 - radial distortion 3
                    Value: 0.000e+000
               P1 - decentering distortion 1
                    Value: -6.402e-005 Deviation: P1: 3.7e-006
               P2 - decentering distortion 2
                    Value: 1.169e-004  Deviation: P2: 4.1e-006
```

**Figure 5: Calibration status report**

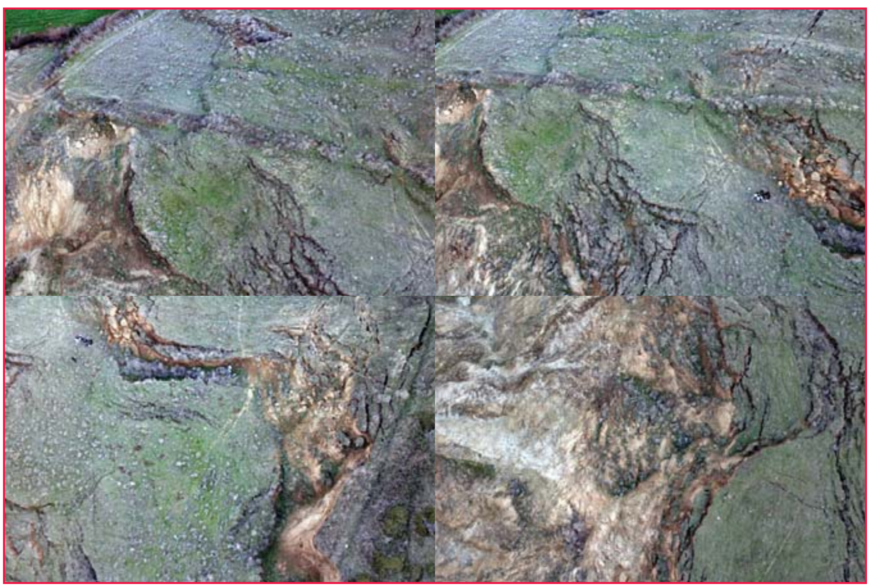

**Figure 6: Some examples of taken aerial photos by UAV**

Thereby, we obtained 3D digital surface model including point cloud with single color and point cloud with exact color from the photographs as seen in Figures 7 (c) and (d). Furthermore, the largest residual for each photo in Figure 8 clearly shows the photo quality production of digital surface models during software process.

In the study area, we get some rock samples from the region. You can see them from Figure 9. The photos of rhyolitic lava, andesitic lava and rhyolitic tuff are given in Figures 9 (a), (b) and (c), respectively. A histogram is a graph that

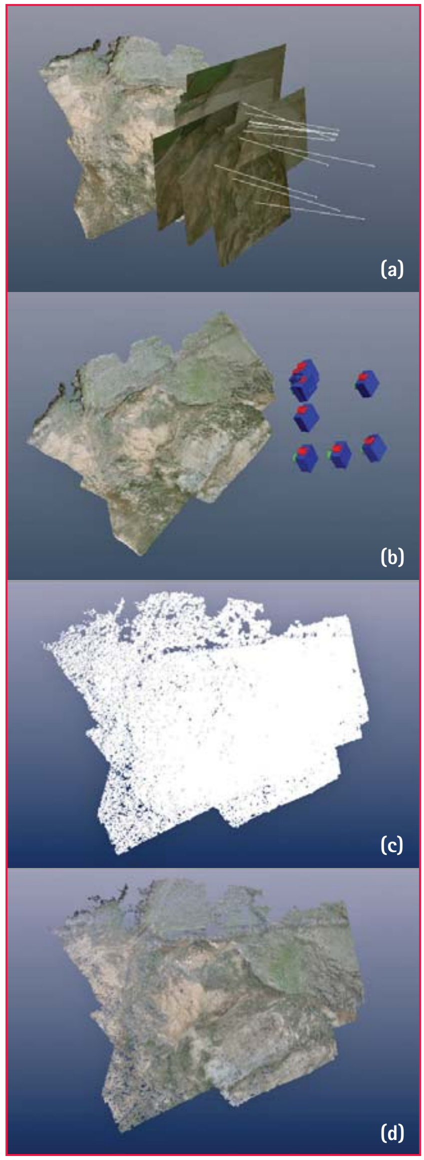


**Figure 7: (a): Image planes from UAV photos. (b): Image frustum plane. (c): Point cloud with single color. (d): Point cloud with exact color from photo.**

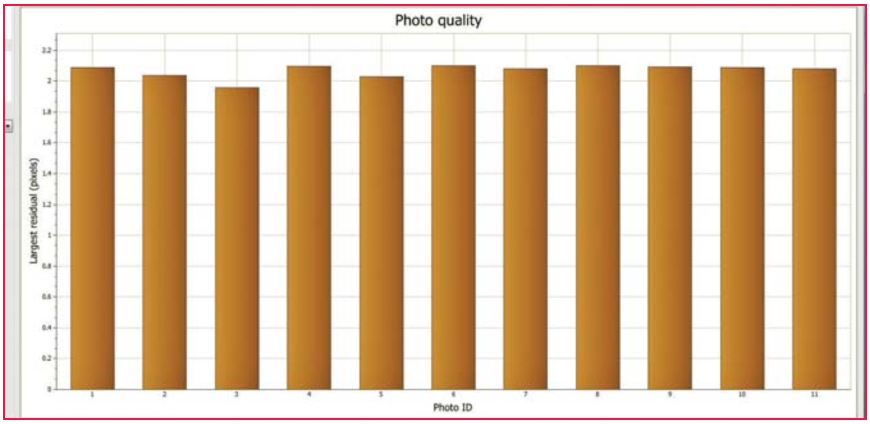


**Figure 8: Largest residual vs photo id**

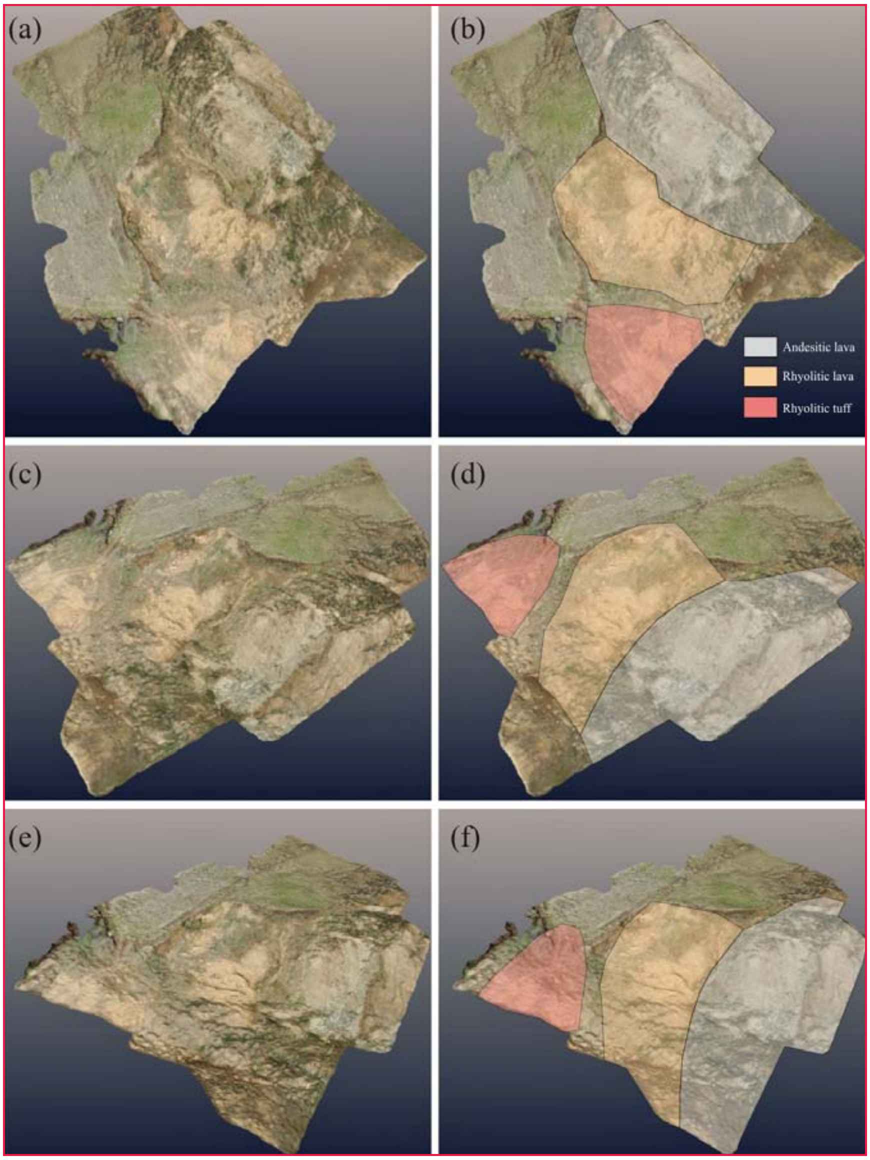


**Figure 10: 3D model of the mining area showing the sub-areas**

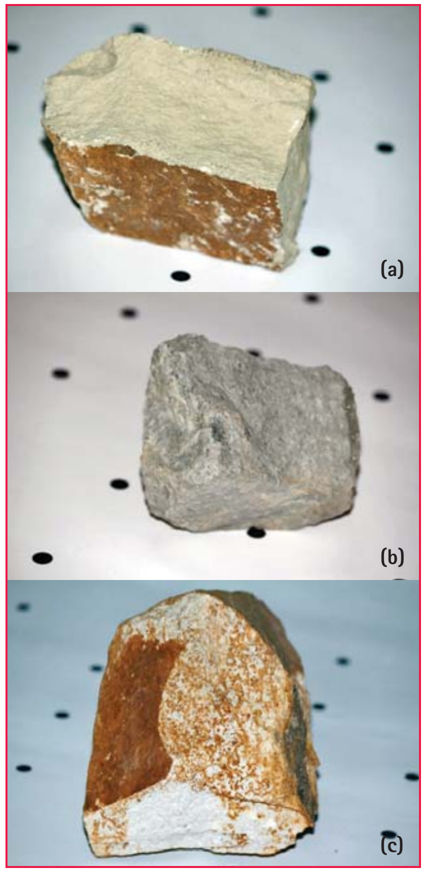


**Figure 9: Taken rock samples from the study area; (a): Rhyolitic lava. (b): Andesitic lava. (c): Rhyolitictuff.**

can help you evaluate a digital image. Histograms can be found on digital cameras and in computer software. We used Photomodeler software. From the RGB histograms of these rocks, the values are regionally averaged for the actual RGB colors (Lichti, 2005, Bachmann et al., 2010, Buckley et al., 2010). The average RGB values of the rocks are obtained. Figures 10 (a), (c) and (e) show the 3D surface models using UAV-remote sensing from three different aspects. Finally, we searched for 3D surface models according to the averaged RGB colors of sampled rocks in order to classify surface characteristics of the study area. The matched areas are covered with related colors. Figures 10 (b), (d) and (f) indicate good matching for landing classifications. Moreover field observations also confirm this.

## Conclusions

In this study, for surface characterization, we showed that a low-cost UAV-based remote sensing approach reveals high-resolution digital surface models. To do it, terrestrial and aerial photographs were taken and their RGB values were compared with each other. Finally, the matched areas, e.g., rhyolitic lava, andesitic lava and rhyolitic tuff were successfully determined, classified and zoned. We propose to use the UAV remote sensing for classifying geological characterization. As for future work, we plan to extend this approach using geological spectrometer tools for increasing inner reliability of the used approach.


## Acknowledgments

This paper is an extended and reviewed version of the study that was presented at the FIG Congress 2014, Engaging the Challenges, Enhancing the Relevance, Kuala Lumpur, Malaysia, 16 – 21 June 2014. This work partly was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) with Project Number 112Y336.


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Jütte, K., (2008), Vergleichverschiedener low-cost Luftbildaufnahme system esowie Einsatzvon Drohnen: Grenzenund Möglichkeiten. In: Bayerische Land esanstaltfür Waldund Forstwirtschaft. Der gepixelte Wald - Fachtagungzur Forstlichen Fernerkundung

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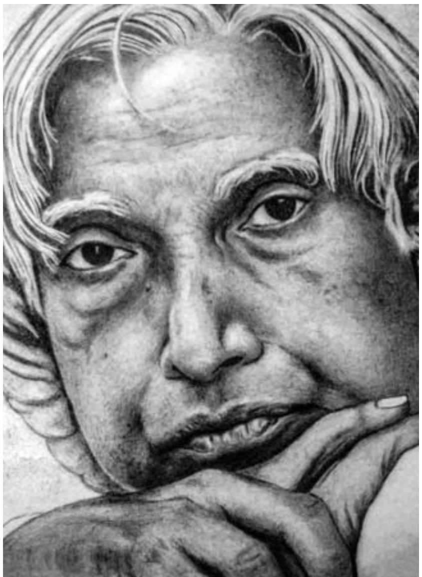
# "Map the earth to enrich the globe"

Remembering Kalam



Oct 15, 1931 - July 27, 2015

Dr A P J Abdul Kalam, The then President of India outlined the priorities and mission for Indian cartographers while addressing the 26th Congress of Indian National Cartographic Association on 23rd November 2006. We present here some excerpts

India has a vision of transforming itself into a developed nation before 2020. There are number of missions which need inputs from cartography technologies that will certainly accelerate the process of development. The programme such as Bharat Nirman Programme including PURA (Providing Urban Amenities in Rural Areas), networking of rivers, infrastructure development in 63 cities through Jawaharlal Nehru Urban Renewable Mission, mapping of earthquake prone areas and recurring floods in north Bihar and Assam require vital inputs at the stage of planning and implementation level. The mission of INCA should be to assist the implementation of developed India vision using their core competence in cartography in partnership with ISRO, NRSA, Survey of India, State Remote Sensing centers, Thematic map making organizations, Indian Remote Sensing Industries, Academia, Research Institutions and other IT organizations. Hence, I would like to talk to you on the topic "Cartographers: Partners in National Development". Let us now look at some typical requirements of rural and urban development programmes of the nation, where cartographers are major partners.

## PURA (Providing Urban Amenities in Rural Areas)

India is on the mission of establishing 7,000 PURAs (Providing Urban Amenities in Rural Areas) in different parts of the country integrating six hundred thousand villages (2 lakh village Panchayats). This integration will bring prosperity to rural India. PURA envisages four connectivities: the physical connectivity of village clusters through quality roads and transport; electronic connectivity through tele-communication with high bandwidth fiber optic cables reaching the rural areas from urban cities and through internet kiosks; knowledge connectivity through education, skill training for farmers, artisans and crafts persons and entrepreneurship programmes. These three connectives will lead to economic connectivity through the establishment of enterprises with the help of banks, micro credit and marketing of products. Since the PURA Clusters need road connectivity, the optimum road alignment without damaging the environment, uprooting the trees and disturbing the water bodies is a prerequisite…

…A combination of ground survey, satellite remote sensing data, and Aerial pictures has to be used to derive relevant maps at larger scale better than 1:10,000 and even at the level of 1:2000 as appropriate in a time bound manner within the next two years.

## Jawaharlal Nehru National Urban Renewal Mission

The Government of India has undertaken several initiatives to encourage sustainable urban development in the country, including the recent declaration of a national incentive-linked fund, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). The JNNURM covers 63 of the largest cities in India. The Ministry of Urban Development (MUD) has been designated as Executing Agency (EA) for the infrastructure and governance component of the JNNURM. India's cities require structured infrastructural development, environmental upgradation and adequate urban infrastructure, particularly the planned sewage and drainage system. The entire infrastructure needs improvement quantitatively and in qualitatively. Urban development and management is necessary to deliver better quality of life to our citizens, considering the local and national economic growth. Thus, JNNURM envisages provision of modern drainage system, provision of drinking water in each house, electrical and electronic connectivity, rain water harvesting and water recycling and provision of congestion free roads. JNNURM is a time bound programme. It is very important for the cartographers to provide cartographic data for each of the 63 cities and towns, using the satellite imagery coupled with GIS…

## Disaster Management Earthquake

…A powerful-enough earthquake just a few seconds in duration can still make current maps suddenly out of date, at the same time severing power lines, gas mains and water pipes. Secondary disasters such as landslides may have taken place in some areas. Satellite images can provide updated views of how the landscape has been affected, while images before and after the event enable authoritative damage assessment as a basis for planning remedial action.

### Flood and water management

…Cartographers should provide high resolution maps in partnership with agencies involved in satellite imagery and aerial photography for planning water harvesting and water management system leading to flood control even in the steep slopes of hill area.

### Flood control through Layered wells

There is an urgent need to find longterm solution to control flood, store and utilize the surplus water during drought. In the Gangetic region, I have recommended construction of layered wells in the entry points of Kosi river. Normally the flood water has certain dynamic flow conditions. The layered wells assist gradual reduction in dynamic flow velocity after filling each storage well. The water thus stored will be useful during shortage period. Similar solution can be found for the north-eastern region…

## Mapping Geothermal potential

…May I suggest to the cartographers, to map the geothermal resources in Andaman & Nicobar Islands, of the total 300 islands I understand one or two islands are having active volcanoes. Also, Himalayan states may have tremendous geothermal potential. These are also required to be mapped in a time bound manner.

## Technology enabled cartography

To address all the inputs needed for the above programmes, we need to use the latest scientific technologies and tools. In this context, the application of Information Technology in the form of GIS, Satellite Remote Sensing, Satellite photo-grammatry, satellite communication and Internet play a vital role. India has planned for a series of satellites specifically for cartographic applications. The first in the series, CARTOSAT-I launched in May 2005 is the first high resolution satellite that collects the details of terrain surface in stereo mode with the spatial resolution of 2.5 meters. As of today, I understand that more than 90% of the country is covered with stereo images. These images could also be used for better urban planning, cadastral level information of land and water resources. This satellite mission has enabled developing Digital Elevation Model (DEM) This elevation model is useful in GIS environment, providing a terrain model to facilitate drainage network analysis, watershed demarcation, erosion mapping, contour generation and quantitative analysis like locationdistance-area-volume calculation…

…Yet another challenge to be addressed by the cartographic community is how do we ensure data integrity, interoperability and accuracy while fusing data from disparate data sources. Also advances in other technologies like GPS, mobile telephones, digital cartography, and photogrammatry will complement the cartographers in their endeavours for national development.

## Missions for Cartographers

Since I am in the midst of Cartographers, I thought of giving the following six missions relevant to Vision 2020 for immediate implementation.

1. Creating a network of all organizations and cartographers participating in this Congress so that they can interface and provide inputs for the development of modern cartographic products required for national development missions.
2. Bringing out large scale maps using advanced technologies for various national development programmes like PURA, interlinking of rivers, survey/resurvey of cadasters, Urban development, metro rail, water ways.
3. Provide cartographic inputs to drought, flood and earthquake prone areas to the disaster management teams for effective planning of disaster management delivery system.
4. Making available high resolution digital maps produced in India and placing the maps on website thereby creating virtual Earth for India for easy access to its citizens in a time bound manner with suitable policies and adequate security mechanism.
5. Identifying wastelands which are essential to take up Jatropha cultivation for bio diesel production. Cartographers should come out in identifying the exact quantum of wasteland available in the country and help the government and farmers for enabling the Jatropha cultivation.
6. Training and building a human resource team which can face the cartographic challenges of the twenty first century.

Cartography has come a long way from the days of Ptolemy and is playing a major role in our lives through new technologies such as GIS, GPS. I am told that most of the mapping of the western world is done in Delhi, Hyderabad and Bangalore. There is a need for a campaign to increase the awareness of the common man regarding utility of geospatial data and its use. Cartographic community has a key role to play in national development and I am sure you will provide value added services to all national missions.

# Enabling Technology for Citizen and Community Tenure Rights Protection

This paper outlines the progress of the FAO SOLA open source software over the past four years and how it has evolved from a system supporting registration and cadastral functions in a typical land office as a result of its implementation in 6 countries (including 7 states in Nigeria)

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Food and Agriculture Organization of the United Nations, Rome

**Andrew McDowell**
Food and Agriculture Organization of the United Nations, Rome

**MariaPaola Rizzo**
Food and Agriculture Organization of the United Nations, Rome

The main reason for FAO's initial involvement in open source land administration software was that in the developing world, the move from paper based tenure records and related processes to computerized systems based on digital data flows had been slow, costly and often unsustainable. A different approach was required to one based largely on proprietary software and repeated software development initiatives in different countries providing similar functionality that mirrored paper based processes. Out of the initial FAO 'Solutions for Open Land Administration' (SOLA) project came a system that provided support for registration and cadastral functions in a typical district land office and a small open source community (Pullar et al, 2012). The initial SOLA solution (now called 'SOLA Registry' was piloted successfully in Nepal, Samoa and Ghana involving local teams of software developers during 2012 (Pullar, 2013).

The SOLA piloting effort coincided with the Committee on World Food Security's endorsement of the Voluntary Guidelines for Responsible Governance of Tenure of land, fisheries and forests in the context of national food security (VGGT) in May 2012 (FAO, 2012). With this endorsement, FAO took on a lead role in the global effort to assist countries, especially in the developing world, to implement the VGGT. In that role, FAO recognized very early that many of the principles encapsulated in the VGGT implied the use of technology including the use of computerized systems. For instance, it is expected that land administration agencies any where in the world must facilitate transparency in the authoritative tenure records they hold and also in the performance of the services they deliver to the public. Current expectations of transparency imply as a minimum computerized indices and computer generated reports. Most commonly transparency implies computerized access to actual tenure records and service delivery by land administration agencies. In this way (and others) land administration agencies can provide greater tenure security to the public they serve.

The VGGT do not just apply to formal land administration and they are not just about the governance of land tenure. Considerably more land and other tenure arrangements exist outside of formal systems such as land administration systems and as a result poor and vulnerable groups have limited access to formalized forms of tenure security. For land tenure, the most common approach to address this lack of tenure security has been systematic registration programs. However, such programs are expensive and countries struggle to afford them without the funding that comes from development assistance support. There have been other attempts to address this problem with community property mapping initiatives but these too are often very dependent on external assistance and cease to operate when that external assistance is no longer there.

The protection of tenure rights outside of formal systems rely on community recognition of those rights and in stable situations there are adequate and appropriate forms of tenure protection within the community structure. However, today, most societies are undergoing rapid change and facing many new challenges which weaken measures that may have protected tenure rights in the past. There are also new situations with few, if any, measures to protect tenure rights of vulnerable sectors in society. Responsible governance of tenure (and all that this means) provides the mechanisms to improve the protection of the rights of the vulnerable in these situations.

The VGGT specifically challenge countries to provide mechanisms:

- to identify and safeguard tenure rights not recorded by formal systems;
- to engage with all tenure rightholders in tenure governance processes including customary tenure rights not currently protected by the law;
- to exercise self governance for communities with customary tenure systems;
- to provide protection against unauthorized use of land, fisheries and forest resources;
- to ensure citizen and community involvement in State processes impacting on tenure rights; and
- to support participatory, gender sensitive processes impacting on tenure rights.

With this in mind, FAO in the last year, with the support and funding from its resource partners, has continued its work in developing and making available more and better open source software solutions that provide countries with a greater range of excellent enabling technology options as they devise plans as to how they will implement the VGGT in a way that provides tenure security to all sectors and especially weak and vulnerable groups within society.

## SOLA implementations

As well as improving one country's land administration system, each implementation of SOLA has increased the international SOLA open source community, resulted in more and better software functionality within the generic version of SOLA software and given FAO a better appreciation of what the needs are for future extensions to SOLA. It has also reinforced the importance of training and using local software developers in the software customization that is required to ensure SOLA complies with local laws, regulations, administrative processes and can deal with local tenure records. An essential element in maximizing the likelihood of a sustainable solution is the availability of local software developers capable of providing as a minimum first level software support and ideally, in the future, for these local SOLA software developers being able to extend and modify the customized version of SOLA when new demands are placed upon the SOLA based system.

## Nigeria

FAO's engagement with the Nigeria Presidential Technical Committee on Land Record (PTCLR) and the GEMS3 project pilots for systematic land title registration (SLTR) (funded by UK DFID) came to an end in December 2014 after more than two years. During that time the SLTR processes were piloted and the SOLA systematic registration functionality refined as lessons were learnt. Originally there were SLTR pilots in just two states (Ondo and Kano) but because of interest from other states, SLTR was scaled up in six further states (Kaduna, Kogi, Jigawa, Cross Rivers and Katsina), all involving SOLA. There were challenges in trying to meet the needs of each state, especially concerning the format of 'Certificates of Occupancy' and the acceptance of the 'general boundaries' approach to define parcel boundaries. Claims that SOLA was 'inflexible' often masked a reluctance to change from old and quite dated practices that were neither sustainable in the longer term nor compatible with responsible governance. The parallel effort to produce a SLTR manual defining SLTR processes was helpful in producing a single version of SOLA for Nigeria SLTR that will minimize the software support effort while still giving states the ability to have their own format for Certificates of Occupancy. Over 20 SOLA support and software developers were trained in the time of FAO's engagement with the PTCLR and GEMS3 SLTR work. SOLA also proved its ability to be modified easily to handle changing SLTR processes and to facilitate at low cost the quick scale-up of SLTR in other states.

The challenge now in Nigeria is to provide the state governments undertaking SLTR work with the ability to maintain the data collected through SLTR in a computerized system within state government Deeds Registries.

## Lesotho

In Lesotho, late in 2012, the Land Administration Authority (LAA) (utilizing funding provided through the Millennium Challenge Corporation (MCC) compact with the Lesotho Government) was faced with the failure of a contract to develop a lease management system; one of the main initiatives to establish a modern land administration agency in Lesotho. The need for an urgent alternative solution was required given the MCC compact finished in August 2013. SOLA was seen as the only option given the available time and budget. This confidence in SOLA was well placed and in a little over 6 months an operational system was developed and implemented in the LAA. Using a team of local software developers supported by the FAO SOLA developers, the cadastral

SOLA Nigeria – Systematic Registration

and registration functionality in SOLA was not only customized for Lesotho, but SOLA was also extended to include lease preparation and management functionality, an interface with the LAA corporate finance system to facilitate the collection of ground rent payments, the loading of data from the systematic registration project and the incorporation of the LAA's orthophotos as a layer within SOLA. The challenge with this SOLA implementation has been that with the abrupt end to funding (with the end of the MCC compact) FAO support to the LAA has been limited to remote support. Normally there would have been at least a 6 month period of support including in-country support from FAO but that has been not been possible. There are plans for FAO SOLA support for further streamlining of lease management processes including integrated scanning functionality and replacing Geoserver as the means to publish LAA orthophotos with Mapserver (another open source solution).

## Tonga

Following a Royal Land Commission of Inquiry in 2010, the Tongan Ministry of Lands, Environment, Climate Change and Natural Resources initiated the Land Administration Project with the goal to significantly reduce the backlog of land applications while also improving the governance, accessibility and transparency of all land related dealings in Tonga. It also provided for greater protection of the paper records (deeds, leases, etc.) and reduce the risk of damage or destruction in case of a disaster.

The Ministry realised that automation through a computerized system would be a key component of the Land Administration Project and asked for FAO's support to implement a customized version of SOLA. A 1 year project was approved for the implementation of a Tonga customized version of SOLA with the project starting in January 2013. The project included the training of local software developers in enterprise software development techniques, participation by the developers in the software customization process, as well as training of Ministry staff in the operation of the customized software.

A significant challenge for this project was recruiting local software developers. There is only a handful of experienced software developers in Tonga (a number of whom attended the SOLA Software Developer Training) and none were available to participate in the customization project. Fortunately a young and talented IT graduate had recently returned from overseas and was able to join the project team and assist with the customization.

The customization of SOLA Tonga was successfully completed in November 2013. SOLA was enhanced to support the feudal and lease based tenure system used in Tonga. Approximately 30,000 paper records have now been scanned and loaded into the new system. Apart from greatly improving the security of these records, the Ministry's ability to search and access these records in response to property information requests has improved dramatically.

The Ministry has engaged the local software developer involved in the SOLA customization and are continuing to enhance SOLA Tonga with remote assistance from the FAO SOLA Team.

## Next SOLA release

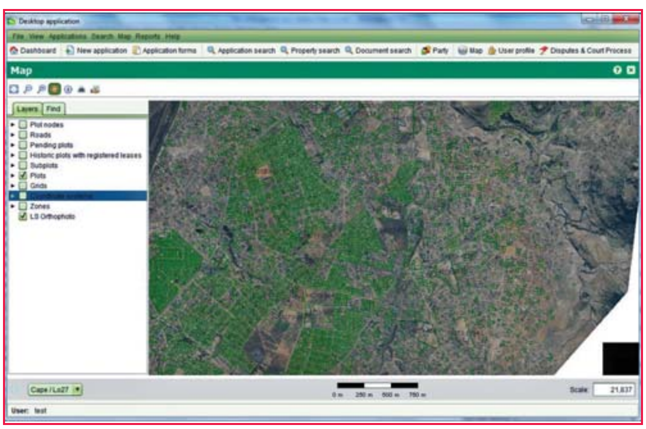
The Easter 2015 release of the SOLA software not only incorporates improvements arising from the recent implementations of SOLA but also includes other further innovations.

The original SOLA software has been separated into 6 separate SOLA software applications each application supporting a different tenure related function. As well, all of these SOLA software applications have been given a new, fresh and common color scheme. SOLA has always had easy to implement multilingual support as a feature of the software but this support has not been implemented comprehensively until this release where SOLA has been made available in 9 different languages. Finally, SOLA Registry (the original SOLA software application) has been extended to incorporate a number of 'Family Safeguard' features to complement its comprehensive disaggregated gender reporting capability.

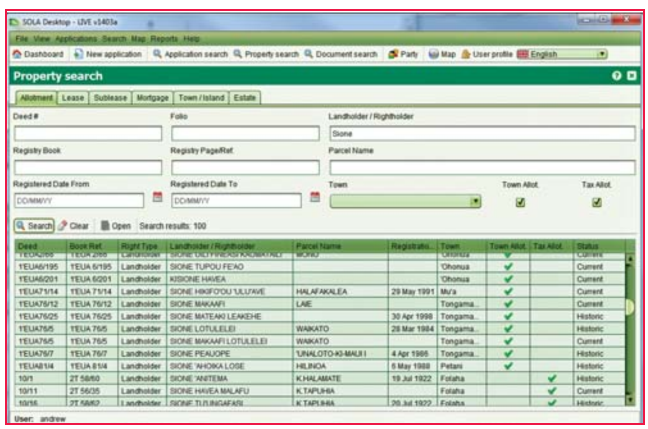
These new features in the SOLA 2015 Easter release are further described below:

### The new SOLA family of software applications

Initially the SOLA software comprised of just one software application that supported



SOLA Lesotho – Lease Management



SOLA Tonga – Feudal and Lease Tenure

registration and cadastral functions and over the last two years this functionality has been extended to cover land administration functions such as systematic registration, lease preparation and management and state land administration. With the release of Open Tenure (a software application for tablets to support a crowd sourcing approach to record tenure relationships by communities that is described later in this paper) in September 2014 it became apparent that the time was right to describe each land administration function supported by the SOLA software as a separate software application. 'SOLA' has been retained as the 'family name' because each of the new software applications uses or has a dependency on the same software architecture including the LADM based SOLA database schema.

The new SOLA software applications are:

- Registry providing enterprise wide support for registration and cadastral functions in a typical district land office including case management of applications through a client desktop application, network server based software and a LADM compliant database .
- Systematic Registration supporting systematic (first time) registration activity based on a project office with a simple local area network (LAN) including the production of public display listings and maps, the generation of title certificates and the digital transfer of this data to a district land office.
- Admin providing system administration functionality available as both a client desktop application and as a web based application. Used in conjunction with other SOLA software applications.
- State Land providing enterprise wide support for state land tasks including lease administration, acquisition and disposal of land and property and the management of state land and properties. Uses both a client desktop application, server side software and the extended LADM compliant SOLA database.
- Community Server hosts Open Tenure captured data, provides web access (and comprehensive searching) to tenure related map and attribute data, allows new property details to be captured without the need for mobile devices (by users with internet access through an internet café) and for community authorized individuals to manage Open Tenure related processes leading to the community recognition of property rights. Web based application typically involving a cloud based server, a LADM compliant SOLA database and an instance of GeoServer publishing (as a WMS service) any aerial or satellite imagery available for Open Tenure community tenure recording.
- Open Tenure provides for the in-the-field capture of property rights (including mapping) through tablet based software (Android and Applie iOS) and the uploading of these details to a Community Server. Existing tenure data and aerial (and satellite) imagery can also be loaded for offline operation. Online operation means that imagery sources such as Google Map can also be used where this is feasible.

Further SOLA software applications being considered for development in the coming year are:

- Mass Valuation supporting the systematic valuation (and re-valuation) of particular categories of properties including the formulation of appropriate valuation models, the calculation of values, generation of listings of proposed new property values, dealing with objections to new property values and the dissemination of finalized property values.
- Public Access providing web based access to map and attribute data held in a SOLA database including details concerning titles, cadastral maps, images of registration documents and survey plans, public display listings (systematic registration, state land and mass valuation) and tenure related applications and service requests.
- Street Address providing for the capture of street centrelines, street names, property numbers and significant landmarks and the dissemination of this data.
- Forest Tenure an extension of SOLA Registry to deal with the administration of forest tenure rights
- Fisheries Tenure an extension of SOLA Registry to deal with the administration of fisheries tenure rights

## Multilingual support

The Easter 2015 release of the SOLA software will include multilingual support in a number of the SOLA applications covering a range of languages as well as a software tool that can be used to incorporate further languages in the future. SOLA multilingual support allows for the on-the-fly language changes without the need to restart the software. Multilingual support covers the user interface, system messages, help files and reference table drop-down lists (with values taken from the SOLA database).

Multilingual support has focused on SOLA Registry where languages supported are English, French, Spanish, Portuguese, Russian, Chinese and Arabic. The SOLA Community Server and SOLA Open Tenure software applications also supports Albanian and Khmer (Cambodian). SOLA State Land supports Amharic (Ethiopia).

The hope is that now the need for a system within a language other than English is not seen as an obstacle for using the SOLA software or as a reason to develop a completely new system to support a land administration function.

## Family safeguards

In computerised systems supporting land administration functions the need to address gender inequalities as related to tenure rights is a topical issue and its importance is reinforced in the VGGT (Principle 4, section 3B, Principles of Implementation, VGGT). Disaggregated gender ownership details are a standard reporting requirement on many World Bank funded land administration projects. Typically this reporting is based on the percentage of male and female owners but this is only helpful in confirming that inequalities exist. In a move to provide more insights into these inequalities and how they can be addressed, SOLA Registry has a disaggregated gender report format that provides greater detail on ownership gender groupings in the hope that this will facilitate bench-marking and the formulation of more targeted interventions to address gender based inequalities.

Another new feature in SOLA Registry has been to incorporate various 'Family Safeguards'. While recognizing that legally backed safeguards protecting women and girls tenure rights vary from country to country, SOLA Registry, includes a facility to note a court domestic violence order and seal ownership details so that SOLA Registry cannot be used by an abusive partner to locate a former partner. It also provides another service where a spouse or dependent (including children) can record their relationship to a property owner and ask to be sent automatic notifications should a transaction be initiated on the identified owner's property. While not necessarily being able to stop the transaction, it may allow a partner or child to initiate an appropriate legal action against the transaction progressing in the case of relationship break-down or inheritance should they consider that their tenure rights will be threatened by the transaction proceeding.

## Evolution of SOLA software architecture

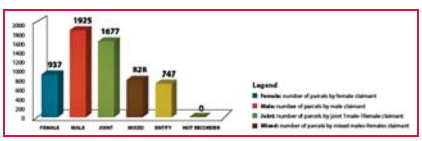
SOLA was originally designed using a layered architectural pattern based around interoperable web services. This was in large part due to the initial analysis identifying two key architectural principles:

1. Use modular loosely coupled and interoperable components
2. Use an Enterprise Application Framework (EAF)

At the time, the rational given for applying these principles were;

a. Loose coupling reduces the complexity of a system of interacting components. It allows making internal changes to one component without affecting other components. It improves availability and stability of the system since problems with one component are less likely to impact other components.
b. Components can be reliably changed more quickly than otherwise would be the case. Functional scope of the components is reduced which in turn reduces their complexity.
c. Interoperability enhances opportunities for reuse, reduces costs by reducing duplication of effort and reducing integration complexity.
d. Typically an enterprise architecture framework will comply with recognised standards ensuring interoperability and significantly reduce the overall coding effort required to produce reliable, scalable and performant enterprise applications.

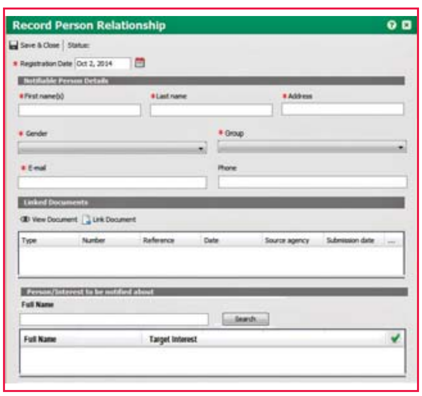
(McDowell 2011)




**An Example of SOLA Registry Disaggregated Gender Report**

The overall goal was to create an architecture that could accommodate a broad range of functional requirements as well as support integration with existing enterprise systems. Between 2011 and 2013 the FAO SOLA development team set about applying these principles and developing SOLA to support registration and cadastral functions of a typical district land office. The following diagram illustrates a logical view of the SOLA software architecture as of 2013 prior to the implementation of the new suite of SOLA solutions. Apart from some minor additions this was consistent with the original architecture envisioned in 2011.

The diagram shows a three tier enterprise application based around web services.


Record Person Relationship

Save & Close | Status:

* Registration Date: Oct 2, 2014

Notifiable Person Details

* First name(s) | * Last name | * Address

* Gender | * Group

* E-mail | Phone

Linked Documents

View Document | Link Document

| Type | Number | Reference | Date | Source agency | Submission date | ... |
|---|---|---|---|---|---|---|

Person/Interest to be notified about

Full Name

Search

| Full Name | Target Interest |
|---|---|

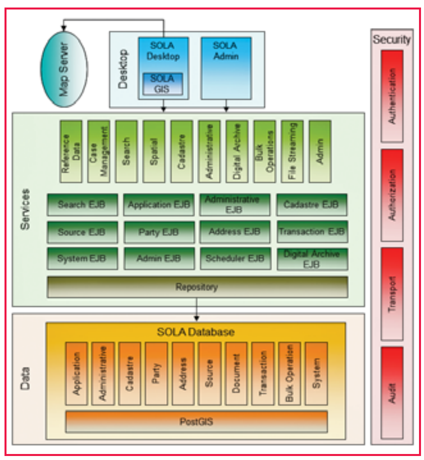
**SOLA Registry Form for Recording a Relationship with an Owner**

A two dimensional layering approach was used to structure the software firstly by responsibility and secondly for reuse. The three structural responsibilities are Presentation (Desktop), Business Logic (Services) and Data. The Business Logic and Data layers are further partitioned into business concepts using web services and Enterprise Java Beans (EJB's) to promote reuse. Security of tenure data was also a primary consideration and industry standard approaches were used for all security aspects. External systems such as Map Servers were also integrated to enhance map navigation through geographic imagery.

### Taking SOLA mobile

With the decision in late 2013 to pursue a mobile app for community recording of tenure claims, the FAO SOLA software development team realized that a review of the SOLA software architecture was required to establish how a mobile app could fit within the existing architecture. A mobile client was not something that had been fully considered during the initial analysis phase and the team assumed some changes to the architecture would be necessary. The review was undertaken by a mobile application expert who made the following key observations:

1) In the 2013 implementation of SOLA, SOLA was intended to work in a walled garden (ie an office local area network)
2) The integration for mobile devices would bring about the need for internet connectivity. The SOLA server was exposing a SOAP based web service interface towards its clients (such as the




**SOLA Logical Software Architecture (2013)**

SOLA Desktop client application) so it was feasible to use the same interface for the integration of additional clients (mobile devices) providing there was the appropriate addition network equipment. There are, on the other hand, several considerations against taking this approach.

a. Security considerations
Exposing the SOLA server directly over the internet would give no control over the type of capabilities that a remote client could access, unless a dedicated, channel aware, access control function was developed on the server itself. However such a function would expose the functionality, currently only internally available to users of the SOLA desktop client applications, to external threats such as DOS/DDOS attacks.
b. Operational considerations
Having a single implementation for both local and remote access to SOLA functions, brings unnecessary functionality to organizations not willing to implement the mobile devices integration. However, a single point of service would introduce a source of cross impact from one access channel to the other. Stopping one service (e.g. deploying a new release fixing a bug only affecting one access channel) would produce an unnecessary downtime on the other.
c. Development considerations
Major mobile applications software development kit (SDK) such as Google's Android and Apple's iOS) have poor support for interacting with SOAP based web services, requiring hand coding of XML building/parsing or additional, platform specific, 3rd party plugins for integration. Using SOLA server as an interface towards mobile devices would then result in either additional development on it or in additional complexity in the development of the mobile applications.

For these reasons, such an approach was not adopted and instead it was decided to implement REST/JSON based interface that was well supported in mobile platforms.

Such an adaptation layer would allow mobile device access to the SOLA server SOAP based web services. Through the use of the same technology already used by SOLA components (Java/JEE), it would be easy to reuse the code implementing the SOAP/XML client in the development of such an adaptation layer. (Toma, 2014)

In addition to recommendations related to the support of mobile apps, the review identified that a web application (the Community Server) would be required to allow users to access and review claim information via the web. The review determined that the architecture and technology stack used for SOLA (Java/JEE) was suitable to support the development of this web application.

### Current state

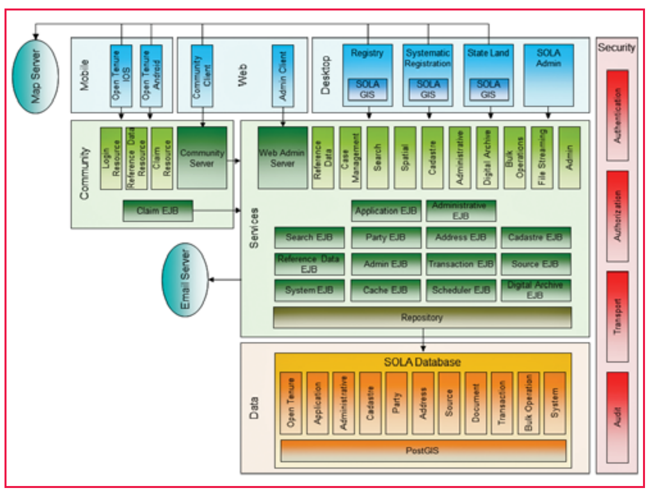
During 2014 the FAO SOLA development team proceeded to implement the Community Server, the Open Tenure mobile apps (for both Android and IOS) as well as the REST/JSON interfaces recommended by the Mobile Application Architecture Review. Automated email capability was added to support enrollment of Open Tenure Community users and new EJB's were added to the SOLA Services layer to support Open Tenure (Claim EJB), improve service performance (Cache EJB) and reduce the number of inter-dependencies between the EJBs (Reference Data EJB). In the same period, the Systematic Registration, State Land and Web Admin solutions were also formalized and implemented. With the move to a suite of solutions under the SOLA umbrella, the original SOLA Desktop was rebranded to Registry.

An important feature of this architecture is that although the components are fully integrated, each new solution only uses the components relevant to its function. For example, the logical architecture for the Open Tenure Mobile apps is shown below. Similar diagrams can be created for each of the new SOLA solutions highlighting the areas of component reuse within the architecture.

Although extensions to the SOLA architecture were required in order to support the Open Tenure Mobile apps, adhering to the original architectural principals established for SOLA has smoothed the transition to the new, more functional architecture. More SOLA solutions are planned for 2015 and the current state architecture will ensure those new solutions can be implemented quickly and effectively.

## 'Open tenure' –community tenure recording

Open Tenure is an open source software app for mobile devices that gives communities and individuals the ability to record tenure rights within their community. It is designed to be used in conjunction with a web based "community server" where tenure details captured with Open Tenure can be publicized and moderated by the community. It is the first SOLA software application to specifically address tenure recording at the community level outside of formal land administration. Although the related SOLA Community Server software uses the same SOLA software architecture and takes advantage of the original SOLA




**SOLA Logical Software Architecture (2015)**

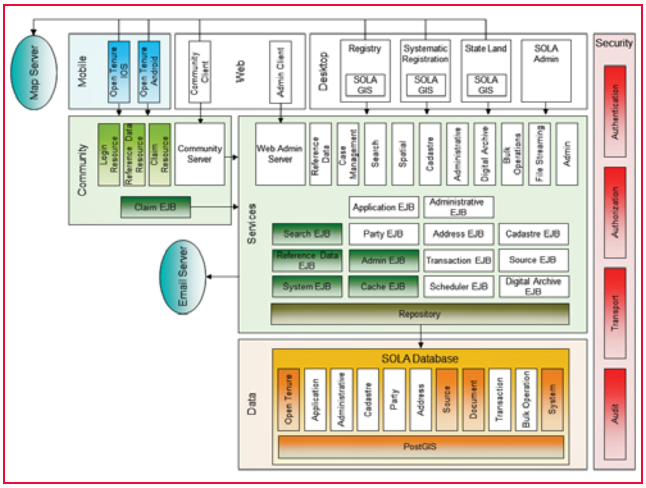
software components as has been explained earlier in this paper, the tablet based Open Tenure software application necessitated extensions to the overall SOLA software architecture and a different software development environment (Eclipse).

Another difference is that while FAO SOLA has recommended in-country (and preferably in-house) SOLA software customization effort and subsequent support for its other SOLA software applications, this is not the case for Open Tenure where the communities expected to use Open Tenure are unlikely to be able to afford that level of software development expertise. Open Tenure can be modified to reflect local needs but this will be a configuration exercise completed when Open Tenure is initially setup for a community and can be done by someone with system administration skills from a remote location.

Open Tenure takes advantage of more affordable technology in the form of mobile devices including tablets and smart phones that certainly in terms of the latter are common within many of these communities. The success of crowd sourcing in many situations (such as Open Street Maps) in developed countries has also been a reminder of the power of community and citizen based initiatives.

Other factors setting the scene for Open Tenure include:

- the success of the FAO SOLA open source software and the general acceptance that open source software provides serious software solutions;
- improved mobile phone network coverage in countries where FAO works;
- the availability of cloud based servers (to host and provide community access to the Open Tenure captured tenure details);
- the publication of the FIG/World Bank 'Fit-For-Purpose Land Administration' report that encourages the use of 'aerial imageries';
- the recent ratification of the Land Administration Domain Model (LADM) as an international standard (ISO 19152) and international exposure given to the Social Tenure Domain Model (STDM) as an extension of LADM to more easily accommodate tenure relationships found in customary tenures and tenure relationships in informal settlements; and
- the 2012 endorsement of the VGGT by the Committee on World Food Security.




**Open Tenure Logical Software Architecture**

## Software development

A multi-national team coordinated from FAO Headquarters in Rome, has been involved in the development of Open Tenure and the other SOLA software applications. Initial design work for Open Tenure began in December 2013 with the Android version of Open Tenure released in September 2014. The first field test involving a community forest group in Cambodia began in February 2015. Another field test of Open Tenure with indigenous communities in Guatemala is being investigated for later in 2015.

Although other initiatives involved in improving the governance of tenure and in particular facilitating the application of Open Data concepts to property tenure rights (for instance MapMyRights Foundation - www.mapmyrights.org) are discussing the establishment of servers to receive, host and publicise tenure rights, no such servers are operating or designed yet. Given that the driver for the Open Tenure development work in FAO was to develop software that would support the crowd sourcing of tenure rights, it was necessary to develop both an in- the-field client app to run on mobile devices as well as a Community Server system that could store, provide access to and support the 'office' (non-field) community processes to moderate the collected tenure details.

For this reason, it was decided to capitalize on the existing SOLA software development effort and create a web version of SOLA, the SOLA Community Server. This component was developed using Java, the Netbeans IDE and involved extending both the SOLA software code (available at www.github.com/SOLA-FAO) and the SOLA database structure. The FAO test version of the SOLA Community Server (based on a fictitious community on Waiheke Island) can be viewed once you register as a user at http://ot.flossola.org .

The Open Tenure client application for the Google Android mobile devices was written using Java but was developed using the Eclipse (Kepler) IDE, with the Eclipse Android Development Tools. The Open Tenure software code as well as the (apk) installation file is available through www.github.com/OpenTenure. Ultimately Open Tenure Android version will be distributed free of charge through the Google PlayStore.

Although Google Android is the most common operating system for mobile devices, Apple iOS also has a significant market share of mobile devices. For this reason, once the Open Tenure Android development was well advanced, a second development for an Apple iOS version of Open Tenure was started using the OSX xCode software development application. This iOS version of Open Tenure is expected to be available by the end of February 2015 through the Apple AppStore with source code also available through www.github.com/OpenTenure.

The transfer of data between the Community Server and Open Tenure is in JSON defined data packets which match up with LADM classes defining rights, restrictions and responsibilities (rrr), documents and sources, persons and spatial units. While the focus of Open Tenure is on community tenure recording and mapping in the informal sector, the data packages uploaded to the Community Server are stored in a separate schema within the SOLA database.

When Open Tenure is used within formal land administration there will be a need to modify this database mapping so that uploaded data is stored within regular SOLA database schemas.

In Open Tenure another mechanism (termed 'Dynamic Form Generation') has been incorporated to make it easy to add new fields, lists and data constraints to meet specific local requirements. Using a similar approach to the Open Data Toolkit, users themselves can make these changes in the SOLA (Web) Admin application without any software changes. Once the Open Tenure form changes have been defined, the next time Open Tenure connects to the Community Server, these changes will be reflected in the Open Tenure user interface.

A lot of thought has gone into software usability in the design of Open Tenure. Unlike desktop software applications where you have user manuals and context sensitive help to overcome any usability complexity, mobile device apps do not normally have these mechanisms. With mobile apps the need for intuitive and simple user operations is essential. If your software app has not 'captured' the user in their first few experiences they are lost to you. To ensure Open Tenure is seen as an easy app to use specialist software usability advice has been engaged and this has seen simplified user workflows, standardized user operations that are more inline with other mobile apps and an improved appearance of the user interface. Coupled with the usability improvements, first time tutorials have been added and a series of YouTube videos of screen operations have been created. Time will tell whether this is sufficient or that further work is required to ensure the uptake of Open Tenure by target groups.

## Community recording of tenure rights using open tenure

Open Tenure supports a crowd sourcing approach to the collection of tenure related details working at the community level. The first Google Android version of Open Tenure was released in September 2014 and the first field test of Open Tenure is in the "The Monks Community Forest Area" in the north-west province of Oddar Meanchey, Cambodia and began in February 2015. This field test involves both the usability of the Open Tenure software in a field context and the trialing and refining of community based processes covering the collection of tenure details (including mapping) through to the display of tenure rights that have been moderated by the community.

### Cambodia Open Tenure Field Test

The first Open Tenure field test will involve the community involved in the Monks' Community Forestry area (also known as Sorng Rokavorn Community Forest) located in Cambodia's northwest province of Oddar Meanchey. This community forest area is the largest in Cambodia and covers more than 18,000 hectares. The Monks Community Forestry area is managed by a group of monks from the Samraong Pagoda in collaboration with villagers from 6 villages close to the forest area. The monks apply Buddhist principles of harmony with nature to inspire protection of the forest resources. They regularly conduct forest patrols to control illegal logging and hunting. The forest is home to a wide array of threatened and endangered species such as banteng, green peafowl, and white-shouldered ibis. It also provides an abundance of non-timber forest products such as resin, mushrooms, rattan, and bamboo, to support local livelihoods.

While the outer boundary of the community forest area has been clearly demarcated and mapped resulting in official Community Forest tenure status, the monks and villagers perceive a need to clarify land claims and other features within the community forest area.

The Monks' Community Forestry community is seen as an excellent community to engage with on this first field test of Open Tenure. This community is well organized and accustomed to working with external partners (such as FAO) and hence feedback is likely to come quickly and lead to improvements in the software and related community processes. It also provides an opportunity to deal with both land and forest tenures. (Bradley, 2014)

### Suggested Community Processes for Open Tenure

The following processes are a starting point for a discussion with communities envisaging community recording of tenure relationships potentially using SOLA Open Tenure and SOLA Community Server software. Such a discussion would be by way of informing the community of possible processes they could utilize and in the interests of the community receiving 'free, prior and informed consent' (FAO, 2014) before making the commitment to undertake community recording.

These suggested processes begin with initial discussions with the particular community as a whole so that they are well informed on what community tenure recording is (and is not) and the activities that will accompany it.

Members of the community with specific roles such as community recorder, member of the moderation committee and the committee's secretary / Open Tenure administrator are identified and trained in those roles.

Once those preparations are complete tenure recording can begin. In the Cambodia Open Tenure field test in addition to recording ownership tenure rights of rice fields and dwellings, certain areas with community forestry characteristics will also be recorded including areas such as 'Spirit Forest', 'Wetlands' and 'Illegal logging areas'. Before the start of field recording, Community Recorders identify the areas they will be working in over the next day or two and download existing tenure rights data and high resolution satellite imagery from the SOLA Community Server onto their Open Tenure tablets. With these downloads the Community Recorders are able to operate off-line while in the field.

In the field, Community Recorders, using Open Tenure, collect details on the property itself (such as name or identifier and land use), ownership (including multiple owners and defined shares), images of supporting documents, photos of owners and the property and a map of the property. Community Recorders are encouraged to map the property in terms of the satellite imagery but the built-in GPS in the tablet can also be used to confirm the property's location, confirm the geo-referencing of the imagery or define the position of a property corner.

Once field capture of property details is complete and the Community Recorder returns to their base, they are then able to upload the recently captured property details to the SOLA Community Server. Once uploaded the property details are viewable by other members of the community through the web-based Community Server as well as hardcopy maps and listing of all uploaded properties at the pagoda near the Community Recorder's base. If there is a challenge to any of the uploaded property claims, the challenger arranges for a counter claim to be prepared using Open Tenure or directly through the SOLA Community Server. Any such challenge includes all the same details from the original claim to property ownership plus a link to the original claim.

The period of time that a property claim needs to be displayed before it is finalized needs to be decided by each community. In this 'Display Period' the original claimant may upload additional supporting documents, if necessary. Once the agreed upon display time is over, dispute resolution processes will be initiated in the case of any challenges. With un-challenged claims, the secretary to the community moderation committee will use SOLA Community Server to check that there are no missing details and, if there are, request the claimant to provide those details. Once the secretary is satisfied that claims are adequately described and dispute processes are complete, they will organize a meeting of the community moderation committee. At that meeting the moderation committee will confirm, modify or reject property claims and these change in status will be reflected on the SOLA Community Server.

In the longer term, changes in ownership will be reflected on the SOLA Community Server in a similar fashion either using details collected on mobile devices running Open Tenure or directly through the SOLA Community Server.

It should be noted that all these described processes need to be discussed and agreed to by the community at the time of initial engagement and could very well be modified to reflect the specific concerns of each community. Each community will decide on the processes associated with Open Tenure tenure relationship recording and not a law and associated regulations and rules such as would happen in formal land administration. Likewise access to Open Tenure captured data will be decided by the community bearing in mind the interests of self governance of the communities resources. The rather sad history in many parts of the world of external parties exploiting the resources of local communities at the expense of local communities is likely to work against the adoption of open data concepts such as are being promoted in the developed world.

This is not to say that a formally defined process might not be devised in the future that would bring these Open Tenure defined and community moderated properties within the formal land administration system. Technically this is simple. However such a move is one for the community to propose and then for those responsible for formal land administration to define an appropriate legal and administrative mechanism for this to happen.

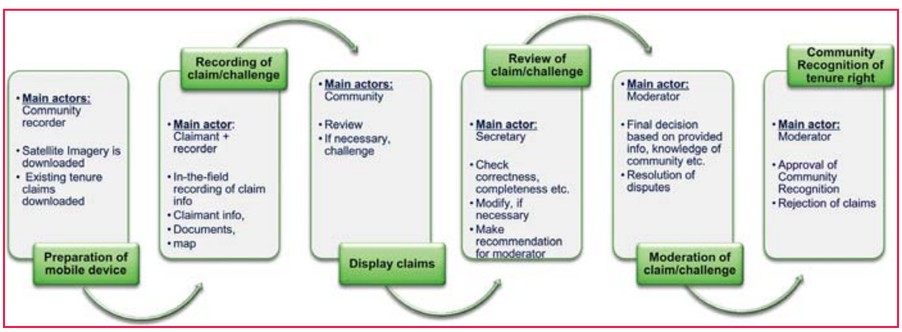
## Open Tenure Software Operation

Open Tenure allows community based recorders using Android based tablets or Apple iPads to record claims to tenure rights. Details captured with Open Tenure include a description of the tenure right, identification of the owners, images of supporting documents and photos and the boundaries of the tenure right in terms of fit-for- purpose map imagery augmented by GPS positions. Once captured these details are stored on an Open Tenure Community (cloud based) Server where they can be viewed by other community members and challenged if there is a dispute. The Open Tenure Community Server also supports processes that lead to community recognition of the recorded tenure rights.

## Future Open Tenure Development

There are a number of issues arising that are likely to influence the further development of Open Tenure.

Existing users of other SOLA applications have expressed an interest in using Open Tenure in systematic registration and in field inspection work by State land managers and valuers. There is also interest in using Open Tenure for citizen recording of boundary disputes and reserve encroachments. These uses of Open Tenure would require modifications to the main SOLA software to copy uploaded Open Tenure captured details into the relevant tables within the main SOLA database tables




**Proposed Processes for Community Tenure Recording using Open Tenure**

in addition to the usual configuration of Open Tenure as occurs when it is used for the first time with a new community.

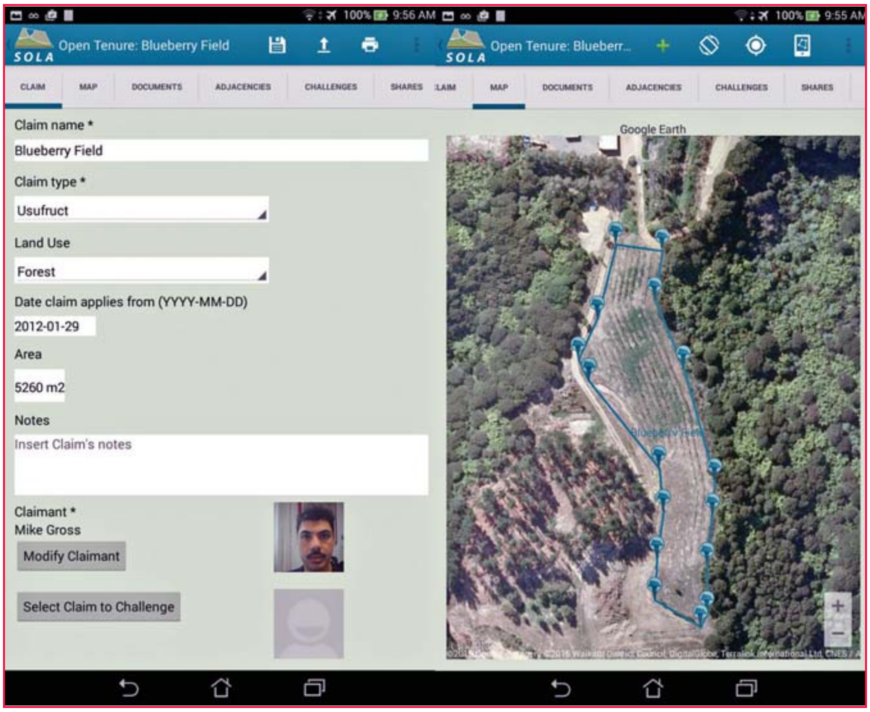
It is expected other forms of Community Server will be established in the near future by other agencies wishing to encourage community level recording of tenure relationships. These may result in changes to how data is structured and transferred between Open Tenure and the Community Server. Likewise, these new community servers may become a source of recent, high resolution, low cost aerial or satellite imagery for download and offline use in Open Tenure and this may necessitate changes to the way imagery is downloaded to Open Tenure.

Another challenge is that although there appear to be Google Android mobile devices in the places where community tenure recording would be beneficial, these devices are primarily smaller smart phones. On smaller screens Open Tenure could be difficult to use, particularly the mapping functionality and a simplified version of Open Tenure may need to be developed.

## Future directions for SOLA software

The full potential of open source software application on mobile devices to address tenure related needs has a long way to go before it has been fully explored. Astute land administration practitioners in as diverse countries as Nigeria, Vietnam and Afghanistan have seen or heard of Open Tenure and despite its initial focus on community recording of tenure relationships have quickly seen its potential for use in a range of land administration field activities. Another positive and interesting possibility would be extending Open Tenure to facilitate greater citizen participation in tenure administration and even leading to a new model for delivering land administration services beyond the current web service based e-government model.

These possibilities deserve attention. Not only are they technically exciting but they would advance the implementation of the VGGT significantly.



**Open Tenure Screens**

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*The paper was presented at the "2015 World Bank Conference on Land and Poverty" The World Bank - Washington DC, March 23-27, 2015*

## EuroGeographics contract with Eurostat

EuroGeographics has signed a contract to provide pan-European geographic information and related services to Eurostat, the statistical office of the European Union. Now staff at the European Commission can access geospatial data from National Mapping, Cadastral and Land Registry Authorities through its geographical information service, GISCO. *press@eurogeographics.org*

## Geocoded reference system to meet demand for integrated data

Growing demand for data analysis across user-defined geographical areas is driving the need for a geocoded point-based reference system says UN-GGIM: Europe.

A report on priority user needs by the working group on data integration found that many no longer require the fixed output areas of traditional surveys and censuses. It recommends that all countries in Europe work together to create a geocoded spatial reference framework for statistics which uses consistent unique identifiers to reference relevant information. The report, which is the first deliverable from UN-GGIM: Europe, highlights examples of best practice in responding to user needs at local, national and European level from Member States, as well as the European Commission and European projects. These demonstrate how the integration of geospatial data and statistics can be used to achieve and monitor key UN Sustainable Development Goals relating to Dignity, People, Prosperity and Planet.

It makes five recommendations that member states:

- Support the development of a European Spatial Data Strategy based on comprehensive National Spatial Data Strategies.
- Initiate a process to increase the number of national authoritative geospatial datasets to better meet stakeholders requirements.
- Consider the requirements of National Statistical Institutes to provide geospatial information for following trends and changes in the environment.
- Promote the use of geospatial workflows and technology as key to advancing the integration of geospatial and thematic information.
- That Member States promote the use of geospatial workflows and technology, in particular for the Census 2021. *www.un-ggim-europe.org*

## SAP accelerates geo-enabled access to enterprise data

SAP has announced it is offering new capabilities to turbocharge spatial intelligence by simplifying, accelerating and geo-enabling access to enterprise data. In the era of the Internet of Things (IoT), proliferation of low-cost location-aware devices is augmenting enterprise data with the "where" component. The SAP HANA platform can help break the silos between enterprise and GIS systems, enabling companies to get more value from corporate data and uncover trends and patterns in a visually intuitive manner. *www.sap.com*

## CloudCities released

SmarterBetterCities has announced the public release of CloudCities, which is an intuitive 3D city service with features for community engagement, easy city data sharing and analytics. Think of it as a YouTube for your 3D city models. Stakeholders can easily explore new city developments and observe existing places they live, work and visit. Dashboards provide detailed information about space allocation, energy consumption and costs. Stakeholders can contribute valuable feedback instantly, start discussions and suggest new proposals even during public hearings or from home. *https://cloudciti.es*

## Honolulu unveils extreme Tsunami evacuation zone

The city of Honolulu has unveiled a new set of Extreme Tsunami Evacuation Zone (XTEZ) maps, to prepare for extreme earthquakes. The maps have been developed by the city's Department of Emergency Management (DEM) along with the Hawaii Emergency Management Agency and the University of Hawaii. City officials have also introduced a free disaster preparedness smartphone app called Ready Hawaii, which has been designed to enable residents and visitors develop family disaster plans. It'll also help residents learn about hazards and disasters in Hawaii.

## GIS-mapping for TB patients in India

In a bid to ensure that tuberculosis cases in the country do not escape detection, a GIS-based mapping and tagging of TB patients, which will provide a real time and a dynamic way to represent disease information on maps, is on the anvil. The move gains significance, as India has the highest number of TB cases in the World, according to the World Health Organisation. *www.asianage.com*

## ICIMOD bags Humanitarian GIS Award

The International Centre for Integrated Mountain Development (ICIMOD) has been awarded a 'Humanitarian GIS Award' for its contribution to the disaster response efforts of the government of Nepal in the aftermath of the recent earthquake in the country. The award was announced during the 2015 International User Conference of the Environmental System Research Institute (Esri) in San Diego. In close collaboration with Nepal's Ministry of Home Affairs (MoHA) and with technical support from Esri, ICIMOD developed and deployed the 'Nepal Earthquake 2015: Disaster Relief and Recovery Information Platform' (NDRRIP). *http://www.ekantipur.com*

## Bosch and TomTom to develop digital maps

German auto supplier Bosch and Dutch digital mapping company TomTom will be working together to develop high-definition digital maps needed by self-driving cars. The new maps will contain a localisation layer and a planning layer for cars to calculate their position on a road. Bosch will provide technology to make TomTom's digital maps more accurate and better able to incorporate data produced by a vehicle's systems. *WSJ*

### River Ganges navigation capacity improvement

The Inland Waterways Authority of India (IWAI) is investigating measures to augment the navigational capacity of the River Ganges, under the Jal Vikas Marg project. HR Wallingford (UK), alongside project partners Howe Engineering Projects (India) and PMC Project (India), will undertake a package of river modelling, geomorphology, dredging, engineering and navigation feasibility studies.

### GAGAN dedicated to India

On 13th July, 2015, New Delhi, the GAGAN facility was launched by Shri P Ashok Gajapathi Raju, Hon'ble Minister of Civil Aviation in the august presence of Shri R.N. Choubey, Secretary, Civil Aviation, Smt. M Sathiyavathy, Director General, DGCA, Shri R K Srivastava Chairman, AAI and Dr YVN Krishnamurthy, Scientific Secretary, ISRO. On this occasion HMCA handed over the Completion Certificate to the Chairman, AAI.

Speaking on the occasion Secretary, Civil Aviation dwelled upon popularizing the system amongst the neighboring countries and other countries in the catchment area. He also emphasized the need for meeting the end users to further popularizing the system. He further insisted that use of GAGAN services should not only be used for the Civil Aviation but also for broader logistics services so that efficiency and reliability of logistics and other industries are equally benefitted from this technology.

### Antwerp airport landings soon to be based on satellite data

Belgocontrol, the agency in charge of safety in the Belgian airspace, will implement a new procedure for the arrival of planes at Antwerp airport from December 2015, reveals the organisation. Planes will land following satellite data instead of ground installation data as of the end of the year. "Belgocontrol will later implement the same procedure in the 4 other airports within its remit," which are Brussels, Charleroi, Ostend, and Liège airports, they add. One of the advantages of the satellite data technique is that planes can "use landing strips not equipped with ILS installations (Instrument Landing System) when visibility is reduced." *http://brusselstimes.com*

### GLONASS and BeiDou joint operation

Russian and Chinese global navigation satellite systems are well suited to meeting BRICS members' civilian needs, chief analyst for GLONASS Union, Andrei Ionin, told Sputnik. "All the studies show that the two systems [can] solve all civilian objectives." He pointed to the key importance of developing GLONASS within the BRICS framework. The analyst estimated that GLONASS spends $1 billion annually to service its navigation system, arguing that it needs to be offered on the BRICS platform to be commercially viable. Brazil, India and South Africa, along with Russia and China, are the five nations of the BRICS emerging markets, accounting for one-third of the world's economy and 40 percent of its population. *http://sputniknews.com*

## China adds 2 satellites to Beidou network

China has successfully launched two more satellites adding to 17 already in orbit. Launched from the Xichang Satellite Launch Center in the China's southwestern Sichuan Province, the two satellites were the 18th and 19th for the Beidou Navigation Satellite system. They were sent into their present orbits by a Long March- 3B/ Expedition-1 carrier rocket 3.5 hours after the launch. *http://tech.firstpost.com*

## ISS Reshetnev building new facility for antennas and feeder devices

Russian satellite manufacturer ISS Reshetnev is building a facility with a total area of more than 19,000 square meters for producing antennas and feeder devices for satellites. The building will house both design departments and production areas. It is constructing the facility within the framework of Russia's federal target program "Maintenance, Development and Utilization of the Global Navigation Satellite System Glonass for the years 2012 to 2020." The facility will include workplaces dedicated to thermal and vacuum, vibration and high frequency tests to verify characteristics and the reliability of satellite payload components. *www.satellitetoday.com*

## Tracking Space Junk With GLONASS

Russia and Brazil are considering a joint project that will detect and track space junk orbiting the Earth, Russia's President Vladimir Putin said at a meeting with his Brazilian counterpart at the sidelines of the BRICS summit. He thanked president of Brazil for agreeing to host two ground stations servicing GLONASS. *http://sputniknews.com*

## Bluesky announces Prototype UAV Flight Restriction Map

Aerial mapping company Bluesky has produced a prototype map showing where it may be unsafe or even illegal to fly UAVs. It has combined an expertise in flight planning and 3D aerial mapping with various geographic datasets to come up with the concept of a UAV Flight Restriction Map for the UK. The map is designed for commercial operators of UAVs and includes 'No Fly Zones', areas where further advice should be sought as well as areas where no restrictions on flying are currently in place. Currently operators of UAVs in the UK must comply with Civil Aviation Authority (CAA) regulations if they plan to undertake 'aerial work', while those equipped for data acquisition and or surveillance must obtain permission before 'commencing a flight in a congested area or in proximity to people or property'. *www.bluesky-world.com*

## PTFS unveils Droneware

Progressive Technology Federal Systems Inc. (PTFS) has introduced Droneware™, a Geospatial Content Management System (GeoCMS) for Unmanned Aerial Systems (UAS). It facilitates the storage, discovery and dissemination of virtually any type of sensor data captured by a UAS. A thin client/server-based solution requiring only a web connection, Droneware runs on a PC in the office or handheld device in the field enabling the user to interrogate local or remote UAS data storage anytime from anywhere. *www.PTFS.com*

## NAAA launches UAV safety campaign

The National Agricultural Aviation Association (NAAA) has launched a UAV safety campaign to raise awareness and prevent accidents between UAV operators and low-altitude manned aircraft. The first public outreach tool in the safety campaign is a UAV "safety stuffer" designed for aerial applicators to share with farmers and other agricultural stakeholders. Sized to fit into a No. 10 envelope, the double-sided insert illustrates the safety concerns ag pilots have about hard-to-see UAVs and provides recommendations for safe and responsible UAV operations in rural areas. *AgAviation.org/uavsafety.*

## eBee Canada's First Compliant Fixed-Wing UAS

Swiss UAS manufacturer, senseFly, sees its eBee as the first fixed-wing system to be designated a 'compliant small UAV' by Transport Canada. Canadian companies that employ drones for civilian applications must hold a Special Flight Operations Certificate (SFOC), unless qualifying for an exemption. An SFOC typically features an approved term of just one year and applies to a specific region.

## AirMap raises $2.6m to help drone operators

A startup called AirMap Inc., based in Santa Monica, USA has created software and systems that help drone operators fly only where they are allowed and welcome to do so. It has raised a $2.6 million round of seed funding to grow its business and expand upon its airspace-mapping and data visualization system. Besides keeping abreast of the shifting, regulatory landscape, and displaying off-limits areas on maps, the company maintains a "don't fly over" registry, NoFlyZone.org, to log the preferences of various private citizens, businesses and other organizations on the ground. *http://blogs.wsj.com*

## Sony takes off into drone market

Japanese technology giant Sony is all set to take off into the drone market. The company is collaborating with a Tokyo startup called ZMP, which specialises in autopilot technology. And they are jointly starting a new company called Aerosense. But, the new venture will not be selling drones. Instead, it will be leasing UAVs to business customers for measuring, surveying, observing, and inspecting purposes. Washington Post

## ISRO earns $100 million by launching 45 foreign satellites in space

According to Indian Science and Technology Minister, Mr. Singh, India has earned nearly 100 million USD (Rs 637.35 Crore) in revenue by launching 45 foreign satellites into space from 19 countries till date.

Mr. Singh provided the revenue details earned by Antrix - the commercial arm of ISRO - from launching foreign satellites into orbit. About SAARC satellite, "While the cost towards building and launching SAARC satellite will be met by the government of India, the cost towards ground system is expected to be sourced by respective SAARC countries. The objective of this project is to develop a satellite for the SAARC region that enables a full range of services to all our neighbours in the areas of telecommunications and broadcasting applications like television, DTH, tele-education and disaster management," he further elaborated. *www.indiatimes.com*

## Malaysia to use RADARSAT-2 data

Global communications and information company, MDA, has been awarded three contracts by the Malaysian Remote Sensing Agency (MRSA) to provide earth observation satellite RADARSAT-2's data to the agency. It would also set up a ground station to process the information and provide training to develop a variety of products.

## EC, China to cooperate on RS research

Officials from the European Union and China have signed a new collaborative research arrangement in the area of remote sensing. The deal involves Europe's Joint Research Centre (JRC) and the Chinese Academy of Sciences' Institute of Remote Sensing. The cooperation will be reinforced and extended to promising areas, such as air quality, human settlement detection and characterisation, land and soil mapping, land cover mapping, digital earth sciences and agricultural monitoring.

## Teledyne awarded contract for Space-based Imagery

Teledyne Technologies subsidiary, Teledyne Brown Engineering, Inc., has entered into an agreement, valued at $15 million over a multi-year period, with NASA for the provision of hyperspectral remote-sensing imagery from an instrument to be based on the International Space Station (ISS). The hyperspectral instrument, being built by the German Aerospace Center (DLR), will be integrated by Teledyne onto the Multi-User System for Earth Sensing (MUSES) earth-observation platform on the ISS. As the first instrument to be installed on the MUSES platform, the hyperspectral sensor is an advanced spectrometer, working in the wavelength range from visible through the near infrared, which is expected to be capable of acquiring more than 70 million square kilometers of data each year. The MUSES platform will host up to three other Earth-observing instruments at a time for additional commercial or government imaging applications. *www.teledyne.com*

## Nokia's HERE Maps sold to BMW, Daimler and Volkswagen

After months of negotiation, Nokia sells the HERE Maps division to the German consortium, BMW, Daimler and Volkswagen for $2.71 billion (£1.73 billion). The deal would see HERE Maps turn into an open platform, which all car manufacturers can use for navigation and mapping inside vehicles. The three German car makers plan to offer the platform to Fiat Chrysler, Renault, Peugeot, Ford, Toyota and General Motors, allowing them to use the mapping service for free without licensing issues.

## BSNL Launches Mobile Broadcast Service BSNL buzz

BSNL, India has launched, BSNL Buzz, a cellular broadcast service to be available on mobile phones. The company has partnered with US based technology firm Celltik for this. BSNL buzz would offer a fully managed high value interactive service on home screen of the users. It would provide interactive services like content, news, contests, subscription packs, coupons and advertising. It will also offer LBS in seven Indian languages such as Hindi, Bengali, Tamil, Malyalam, Kannada and Telugu besides English. *www.teleanalysis.com*

## Smartwatch navigation app for the visually impaired

Novartis has released a new Apple Watch and Android Wear app geared at helping visually-impaired people navigate their environment. The app is one of two Via Opta apps that have been available on the iPhone since August 2014, but a new upgrade adds additional features and brings Via Opta Nav onto a wearable for more convenient navigation. It provides turn-by-turn navigation instructions, similar to driving navigation apps like Google Maps. Voice guidance and vibrations alert visually impaired people to turns, intersections, and landmarks. Users can also ask the app for their exact location, add waypoints to their route, and search for nearby destinations. *http://mobihealthnews.com*



## Transas receives ECDIS type-approval from the Korean Registry

Transas, one of the world's leading providers of integrated navigation solutions, received ECDIS type-approval from the Korean Registry (Korea Marine Equipment Research Institute), making Transas one of a few companies holding an ECDIS certificate from the South Korean maritime authority.

The certificate proves the system's compliance with all ECDIS-related regulations valid for the South Korean Flag state and covers not only Navi-Sailor ECDIS in Premium and Standard configurations, but also all Transas supplementary components for usability benefits and system integration. All tests were successfully passed within one week at the certified Transas R&D facilities. *www.transas.com*

## U.S. Navy, Rockwell Collins collaboration

The U.S. Navy is supporting greater levels of software reuse through a Cooperative Research and Development Agreement (CRADA) with Rockwell Collins for Required Navigation Performance-Area Navigation (RNP-RNAV) Flight Management System.

The CRADA between Rockwell Collins and the Naval Air Systems Command (NAVAIR) Air Combat Electronics Program Office (PMA209) will culminate in a fall 2015 demonstration of RNP-RNAV technologies aligned with the Future Airborne Capability Environment (FACE™) standard. *www.rockwellcollins.com*

# Leica News

## Supercharge Mobile Data Collection with ZenoCollector

Esri Collector for ArcGIS, a configurable mobile app for collecting and editing data in the field, has combined with the Zeno 20, Leica Geosystems' ultra-rugged Android-based professional-grade handheld, in a new solution called ZenoCollector. It uses Collector for ArcGIS as its main user interface and comes bundled with an ArcGIS Online organizational subscription for one year. ArcGIS Online connects ZenoCollector to the ArcGIS platform, automatically synching field changes to enterprise information and giving everyone access to the latest data gathered in the field. Collector for ArcGIS also supports offline data collection. Any updates will be synchronized with the map once the user is reconnected. *esri.com/zenocollector*

## Leica Nova MultiStation in Real Time

National Grid embarked on a seven-year project, London Power Tunnels, to help ensure future electricity supplies for the UK capital. The transmission infrastructure improvements required a network of tunnels to be built across London, to house what has been described as "a new subterranean electricity superhighway." Costain Group, one of the UK's leading engineering solutions providers, was contracted by National Grid to build the tunnels. It used Leica Geosystems' Nova MS50 MultiStation to scan the tunnels and Amberg Technologies' TMS Tunnelscan software to process the generated information during this project. *http://hxgnnews.com/*

## Leica Geosystems launches HDS Virtual Classroom

Leica Geosystems has launched the HDS Virtual Classroom, an online training opportunity for professionals who desire to take their laser scanning abilities to the next level. Taught by experts with extensive experience in all fields of laser scanning, each two-to three-hour live course delves into a common challenge or question and guides students through step-by-step best practices designed to ensure success.

## Trimble Unity Software for Water

Trimble has introduced the latest version of its smart water mapping and work management cloud software—Trimble® Unity™ version 2.0. The version adds new capabilities to support complex water, wastewater and stormwater industry asset maintenance planning and work execution workflows, support for Bring Your Own Device (BYOD) GNSS mapping receivers for smart devices and cloud-based single sign-on integration with Esri ArcGIS Online.

Trimble Unity version 2.0 features advanced asset maintenance capabilities that allow utility customers to quickly search and group various types of utility assets, including meters, pipelines, valves and hydrants, into prioritized collections of work that can be easily assigned to crews for completion. *www.TrimbleWater.com*

## AGCO and Trimble Announce Collaborative Solution

AGCO, a worldwide manufacturer and distributor of agricultural equipment and infrastructure, and Trimble have announced partnership to deliver wireless connectivity between AGCO's VarioDoc and AgCommand® systems and the Trimble® Connected Farm™ solution. The functionality is expected to be available to customers in North America in September and in Europe, Africa and the Middle East in the fourth quarter of 2015.

Deeper integration of AGCO and Trimble technologies delivers a more streamlined approach to total farm management, simplifying the grower's ability to access and act on live machine and task data within a single, Web browser-based user interface. *www.AGCOtechnologies.com*

## Trimble First Educational Centre of Excellence in India

Trimble has appointed Chennai Institute of Technology (CIT) as the first Educational Centre of Excellence in India for their Trimble Buildings business division. The main objective of this initiative is to educate technology students and ensure that the future engineers are well equipped with technology skills that the growing Indian industry employers value.

The Chennai Institute of Technology provides quality technical education with adequate industrial exposure with its innovative teaching methods. The institute will include a special certification course on Trimble's Design Build Operate (DBO) technology in their curriculum where they will teach their students on Tekla BIM technology and also other Trimble Buildings construction solutions. *www.trimble.com*

## More mines turning to SAFEmine in SA

Another South African mine has turned to Hexagon Mining for a safer, more productive future. Exxaro's Grootegeluk coal mine will implement SAFEmine, Hexagon Mining's world-leading collision avoidance and fatigue monitoring technology. The SAFEmine Collision Avoidance System, (CAS) which includes SafetyCentre, TrackingRadar, and FatigueMonitor, is a complete safety package for Grootegeluk. *hexagonmining.com*

## Raytheon Installs First GPS OCX Hardware

Raytheon has installed the first operational hardware for the GPS Next Generation

Operational Control System, known as GPS OCX. The new ground command and control system will significantly modernize U.S. GPS capabilities and manage the next generation of GPS satellites. Installation of the Launch and Checkout System (LCS) hardware was completed in early July at Schriever Air Force Base in Colorado, the eventual home for the new GPS OCX Master Control Station.

GPS OCX will deliver a host of new capabilities, including automation for operational efficiencies, improved accuracy, interoperability with geo-positioning and navigation systems of other nations for better global coverage, and a cybersecurity architecture that provides unprecedented levels of protection. *www.raytheon.com*

## Utility Software Suite PinPoint-GIS by Septentrio

Septentrio new software suite called PinPoint-GIS makes GIS data collection and visualization straight forward. It provides several methods of data collection, based on a standard web browser hosted on the Altus APS-NR2 and a mobile app integrated with Esri's ArcGIS or other GIS mapping systems. Any user of PinPoint-GIS benefits from bringing the data collection process into their familiar GIS environment. *www.septentrio.com*

## BlueStarGPS unveils low-cost GPS/GNSS solution

BlueStarGPS is planning to offer both GPS and GNSS options in a rugged, lightweight and low-cost package. Known as BlueStarGPS, the solution has been designed specifically with sub-meter mapping and data collection performance specifications. It increases accuracy by utilising SBAS corrections, including 3-channel, and parallel tracking SBAS operated by the FAA, the EGNOS, the MSAS (Japan) and the GAGAN (India).

# MARK YOUR CALENDAR

## August 2015

**CPGPS MIPAN'2015**
26 - 28, August
Xuzhou, Jiangsu, China
**www.cpgps.org/new_site/news2015.php**

**UAV-g 2015**
30 August - 2 September
Toronto, Canada
**www.uav-g-2015.ca**

**ESA/JRC International Summer School on GNSS 2015**
31 August - 10 September
Barcelona, Spain
**http://congrexprojects.com/2015-events/15m21/registration**

## September 2015

**GIS Forum MENA**
6 – 9 September
Abu Dhabhi, UAE
**http://gisforummena.com**

**InterDrone**
9-11 September
Las Vegas, USA
**http://www.interdrone.com/**

**ION GNSS+**
14-18 September
Tampa, Florida, USA
**www.ion.org**

**INTERGEO 2015**
15 – 17 September
Stuttgart, Germany
**www.intergeo.de/intergeo-en/**

**ISPRS GEOSPATIAL WEEK 2015**
28 September - 2 October
La Grande Motte, France
**www.isprs-geospatialweek2015.org/**

**EGNOS workshop**
29 - 30 September
Copenhagen, Denmark
**www.essp-sas.eu/news**

## October 2015

**Surveying & development regional conference**
03-06 October
Sharm El-Sheikh, Egypt
**www.sd2015-eg.org/**

**Commercial UAV Expo**
5 - 7 October
Las Vegas, Nevada, USA
**www.expouav.com**

**DIGITAL EARTH 2015**
October 5-9
Halifax, Canada
**www.digitalearth2015.ca**

**20th UN Regional Cartographic Conference for Asia and the Pacific**
5-9 October
Jeju Island, Republic of Korea
**http://unstats.un.org/unsd/geoinfo/RCC/**

**Intelligent Transportation Systems: 22nd ITS World Congress**
5 - 9 October
Bordeaux, France
**http://itsworldcongress.com**

**Geo Empower Africa Summit**
6 - 7 October
Johannesburg, South Africa
**http://itc.fleminggulf.com/geo-empower-africa-summit**

**36th Asian Conference on Remote Sensing**
19 - 23 October
Manila, Philippines
**www.acrs2015.org**

**2015 IAIN World Congress**
20 – 23 October
Prague, Czech Republic
**www.iain2015.org**

**Joint International Geoinformation Conference**
28 - 30 October
Kuala Lumpur, Malaysia
**www.geoinfo.utm.my/jointgeoinfo2015/index.html**

## November 2015

**ICA European Symposium on Cartography**
10 - 12 November
Vienna, Austria
**http://eurocarto.org/**

**International Technical Symposium on Navigation and Timing**
16 - 17 November
Toulouse, France
**http://signav.recherche.enac.fr**

**ISGNSS 2015**
16 - 19 November
Kyoto, Japan
**http://www.isgnss2015.org/**

**Drone World Expo/MAPPS Conference**
17 - 18 November
San Jose, CA United States
**www.droneworldexpo.com**

**GEOTECH RWANDA**
18 - 20 November
Kigali - Rwanda
**www.geotechrwanda2015.com/**

## December 2015

**The Geoinformation Technologies for Natural Hazards Management (7th GiT4NDM)**
8 - 10 December
UAE University
**http://conferences.uaeu.ac.ae/eogc-git4ndm/en/index.shtml**

**9th International Symposium on Mobile Mapping Technology (MMT 2015)**
9 - 11 December
UNSW, Sydney, Australia
**www.mmt2015.org**


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