



**DRONA**MAPS

**R&R**

POLAVARAM

Project Turtle  
Highlights from  
the making of a community

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January 20, 2018

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This document highlights our work on behalf of our clients and communities we serve.

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# Letter to the DM

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January 20, 2018

Shri Kartikeya Misra, IAS  
District Magistrate and Collector  
East Godavari District,  
(Andhra Pradesh), India

Dear Sir,

Thank you for the opportunity of working with the district of East Godavari. Please find attached a brief report on the pilot conducted by DronaMaps for the Rehabilitation and Resettlement project in your district. We understand and are able to deliver according to your technical specifications and operational needs. It would be our privilege to serve the state of Andhra Pradesh and design and implement a home for all the people under the R&R project.

By selecting us, the state gains a partner who:

- Has successfully managed projects of this size, scale, and complexity. We have served organisations and large organisations across the full set of their challenges.
- Can get the job done, quickly, correctly and cost efficiently-- even under pressure.
- Will focus on and deliver improvements in both efficiency and technology to work you to improve your agencies' mission delivery. And do this while being cost effective.
- Brings expertise between public and private sector, you would not have to choose between either.
- Recognises that driving change in the government is hard and that how to do it using rigorous data and analytics, informed by organisational theory.
- Understands the goals and challenges of the Rehabilitation and Resettlement Project.

DronaMaps specialises in 3D image reconstruction and recreating reality digitally. We use our platform as a visual and analytical baseline to deliver projects with efficiency and cost effectiveness. Our success is contingent on our unwavering commitment for driving impact for our clients. During the entire duration of this project, rest assured that you have all our resources, intellectual and infrastructural, being channelled to take this project to a meaningful conclusion.

Thanks,

Sincerely,  
The Team  
DronaMaps Pvt Ltd.  
IT SEZ, Hill no. 3,  
Visakhapatnam, AP

# Impact Study

## The Story

The Rehabilitation and Resettlement project is assigned to build 15 colonies for the residents of 184 submerging villages (based on an under 45.72 m submergence contour estimation) under a stressful deadline ending on 30 October 2018. Our current task was to preserve the data for 5 submerging villages with extreme fidelity in 3D maps, while charting out plans for the colony of Pedimbhimpalli. We visualise both on our 3D platform.

## Our Solution

DronaMaps provided the R&R team with a one stop solution for 3D mapping of old submerging hamlets to contribute to a repository of the land and design the new colonies. Our UAV enabled solutions for the mapping, analysis, and design of new settlements use the patterns emerging from analytics of these hamlets in combination with innovative smart village concepts to influence the design of new colonies.



*(3D CAD model integrated with UAV aided 3D maps for Pedibhimpalli-2)*

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## The Pilot

### 3D maps of habitations:-

- Madipalle
- Dandangi
- Toyyeru
- Penkalupadu
- Gangampalem

### 3D Maps + Design of Colonies

- Mussullakunta
- Pedibhimpalli

### Technical Details

- 3D mapping resolution <3cm
  - 3D Contour interval 20 cm
  - 2D Orthomaps < 3cm
  - 3D Elevation maps
  - CAD integration
- 

## Impact and Results

DronaMaps provided a unified intelligence picture and future repository on the land from submerging habitations and the new colonies being designed

We created detailed CAD models to take the analysis from our drones to another level. We 3D visualised the existing contour of the new colonies & created CAD models on it to accurately model the natural surrounding at record cost-effectiveness, redirecting to major amenities.

DronaMaps UAV aided data collection capabilities allow for data procuring, processing, and analysis in a matter of days, instead of weeks or months.

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## Scope

The repository thus created for the submerging villages not only provides analytics for today but also allows for future virtual reality integrations where in, people would be able to walk through these models and experience the hamlets as they were. The new colonies stay true to the socio-cultural core of the original habitations, with a few innovative twists. In addition to more intelligent design and planning, our platform can allow for project monitoring, and efficient execution of projects. The colony designed can be brought to blockchain networks to create secure and indisputable land records. The fundamental happiness of any community rests in the land they live and cultivate on, it is the relationship with land that we have made it our mission to understand.

# Our Process

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## UAV Deployments | Data collection

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Our team of experts and engineers go where your problems are. This means driving through a narrow winding path in a jungle to reach Mussullakunta (we took a video for posterity's sake). As there are connectivity challenges on the ground, our team spent a day in Rampachodavaram for surveying and formulating our flight plans for the seven separate piece of lands involved in this pilot.

### Planning

We gather historical data, and made flight plans for individual sectors in the area based on the elevation and contour profiles from our pre-assessment surveys. These pre-assess surveys are done two ways, using SAR imagery and satellite data, in addition to the first day on the field where a visual ground-truthing is done for the autonomous plans.

Along with this, we also check for high-points, generate geo-fences, establish Ground Control Points (GCPs), gather the ground data for important landmarks and government buildings, highways, hospitals, and transportation amenities.

Once this pre-assessment and planning is complete, which takes about 20% of the overall project timeline, we are able to deploy our UAVs in a completely automated manner.

### Deployments

The UAV operations are a very serious business. The airspace has to be controlled very carefully, with FRTOL enabled operations. The team comprises of a Ground Officer, a Remote Pilot, and the First Officer. Logistical support is handled via another division, which comprises of a spotters, flight-trainees, and vehicle support. Both teams coordinate over a separate channel with the base team, and the FRTOL is relayed via the mother server to upper management.

Based on the pre-assessment surveys and the elevation grid, we plan out the trajectories for the UAVs and cross-reference that with historical GIS data. This is done to automate the operations to the largest extent possible to ensure maximum safety.

## Deployment Details of the Pilot

Hours spent on the ground

120 hours

Size of the team

4

Area Mapped

122.04 acres



## Processing

Processing a large dataset like this is a challenge unto itself. We address this challenge by optimizing our n-node processing cluster over a large distributed compute grid.

To start of with, the initial data is assessed on the ground itself using the meta-data from the files. This EXIF data helps generate quality reports and overlap percentages, both of which are crucial in either oblique imagery processing or nadir.

At this point, the data then transfers over to the processing team which breaks down the data into chunks of manageable sizes and deploys separate nx4 cluster grids at separate resolutions for the CMVS/PMVS pipeline. This is then extracted and pushed through the higher capacity compute nodes which in turn analyze this data and turn then into highly-dense contour maps. This makes for the baseline for the 3D DEMs and the TIN network models. The process then moves onto grid-scale rendering for the final outputs, which are pushed out through our automated stacks and post-processed before delivery.

## Behind the Curtains | The Technology |

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An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot aboard. The flight of UAVs may operate with various degrees of autonomy – either under remote control by a human operator, or fully or intermittently autonomously by onboard computers.



*(Our P4P on top of the terrace of a village school in Madepalli)*

The following are the different aircrafts used:

- UAVs: (Multi-rotor/Quadcopter) with 28 minutes of flying time for autonomous oblique trajectory flights.
- Fixed-wing UAV with RGB-d+multispectral grid mapping sequencer with 90 minutes of flight time for nadir images.



*(MTD fixed wing for grid flight sequences)*

Utilizing the fully autonomous capability of these customized aircraft, the camera takes hundreds and thousands of overlapping pictures with between 60-80% lateral overlap and between 70-90% frontal overlap, and up to 4-10 degree separation for oblique images. Using advanced computer vision algorithms based on streaming parallel reconstructions and SLAM (which extracts geometry to calculate camera position for generating accurate maps and 3D Models), we then analyze the millions of keypoints in these images to eventually generate an orthorectified 3D digital re-creation model, which makes the basis of our highly accurate maps. Along with Orthomosaic and 3D Elevation data, we also generate the vegetation index files of the same dataset where the NIR and Red-Edge spectral lines come in heavy use.

The UAVs are completely autonomous with manual override, but this comes at a huge cost and effort. To start with, we follow the normal curve of data collection — only the best points and the minimum amount of dataset is sent for processing based on quality reports. This is because 3D processing algorithms are extremely memory intensive, and after a point, more data reduces the overall quality and resolutions for the entire map.

To accomplish this goal, we have designed autonomous flight trajectories for grid and oblique imagery capture using the principles of UAV Trajectory Optimization where we only capture the best, and the most dense points for accurate reconstructions at centimeter level.

The data that these UAVs capture goes into a scalable processing grid. The grid is made up of nx4 units of processing clusters. Each cluster has a 128 core, 768GB RAM, and 4x2048GB SSD units, with 30,000 CUDA cores per cluster. The grid is spun up and scaled as per the load derived from the input channels.

## Technological Scalability

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### Platform

- UAVs based on multi-rotor and fixed-wing autonomous fleet controlled systems in fixed geo-fenced areas for autonomous flights.
- 30,000 CUDA cores per cluster with nx4 cluster grids operating in parallel to handle the processing load.
- Sensors: RGB-d with multi-spectral capability based on narrow band NIR and Red-Edge spectrums.
- Outputs: 3D maps (geo-referenced), orthomosaics, DSMs, DTMs, 3D DEM, TIN Networks and VRMLs, Map Tiles, and Densified Point Clouds.
- Tracing: Database logged outputs with intermediary files for process control flow.
- Security: Encryption at rest with 2048-bit Diffie-Hellman supported communications for end-to-end security over cluster nodes. Processing and Database units are behind the firewall with only the application servers in public domain, controlled by SSL3.0 protected user authentication based on SAML.
- Error Margins: Calculation errors are always maintained within less than the ceiling 1% of the ground surveys. Mean errors are in centimeter scale.

### Scalability

- Back-end processing framework based on containers with scalable virtualized infrastructure and ability to spin up hundreds and thousands of nodes as per load average.
- Data distributed and replicated over three physically separated data-centers for enhanced disaster recovery.
- Institutional Support: Active advisory group of researchers within Computer Vision, Robotics and Machine Learning, and PS2 Cycle.
- Service scalability using UAVs being able to map from 0.3 sq km to 16 sq km per hour and ranging from multi-rotor to fixed-wing aircrafts for nadir and oblique imagery. All UAV operations are completely automated using intelligence from pre-assessment analysis.
- Bandwidth: Redundant dedicated Gbps lines to the data-centers with 10GBe lines between server units within the data-center. Triple level redundancy with three-separations for immediate disaster-recovery and backups. The entire system, including fleet control for UAVs is hosted on our cloud platform, making it very, very safe and scalable.

## Sustainability

- **Relevance:** High resolution centimeter level mapping & 3D models are useful for any planning and development, regardless of the location and department of the government. It's immediate high-level data intelligence, delivered.
- **Cost Effectiveness:** Initial costs are high because of quality requirement (backups, network infrastructure, supercomputing engines, software, delivery) and breakeven costs. Atomized costs per unit are very low when done at scale. Can map an entire state of India (e.g. Andhra Pradesh) in much less than a year with cost effective solution.
- **Financial Viability of Initiative:** Govt.'s savings are estimated to be between 40-60% compared to current surveying and planning techniques when done at scale. There will be structured and scientific planning across over 32 departments and maybe more, at half the cost with immediate high-accuracy data intelligence captured at scale and updated frequently.

## Status Tracking

- Live GPS enabled tracking of all aircraft and operators with by-the-minute flight-planning and monitoring. Automated logging of all operations and audit & compliance ready systems.
- Live monitoring of any actionable areas for any government reporting for status checks.
- All data is uploaded onto the cloud based web platform which can give remote encrypted access to any authorized officer for keeping check on progress reports.

## Getting to Know | The Habitations |

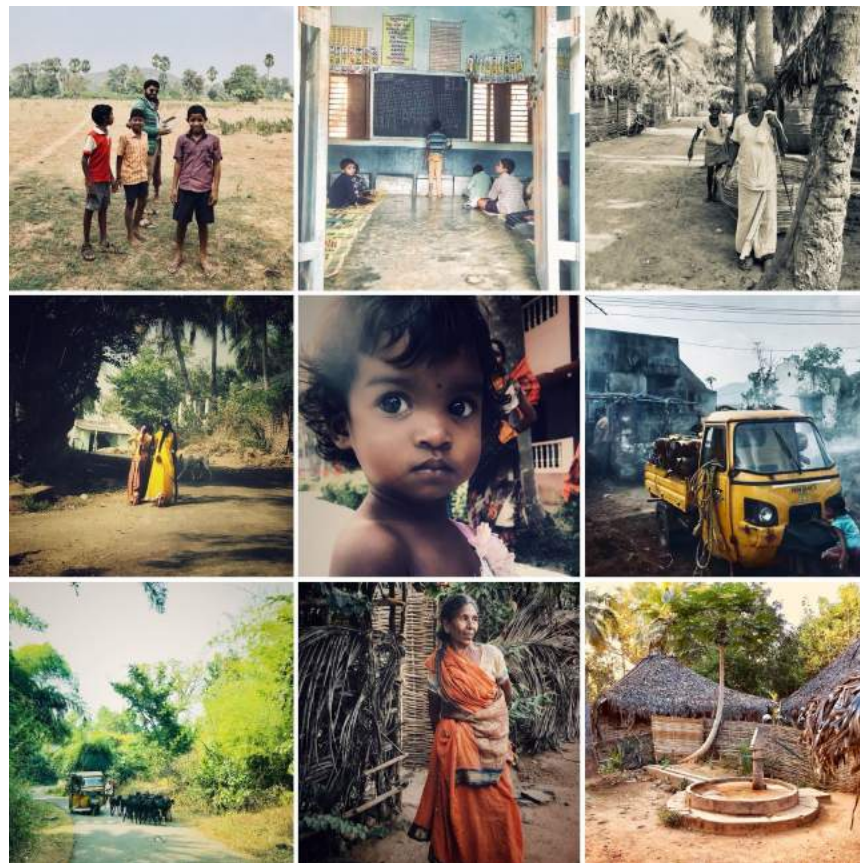
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### Immersion Phase of Design Thinking

Our team spends a few days in the community, getting to know the people, understanding their lifestyle and relationship with their physical environment through conversation and observation to help us design a colony that would be a perfect fit for both.

Key Factors:

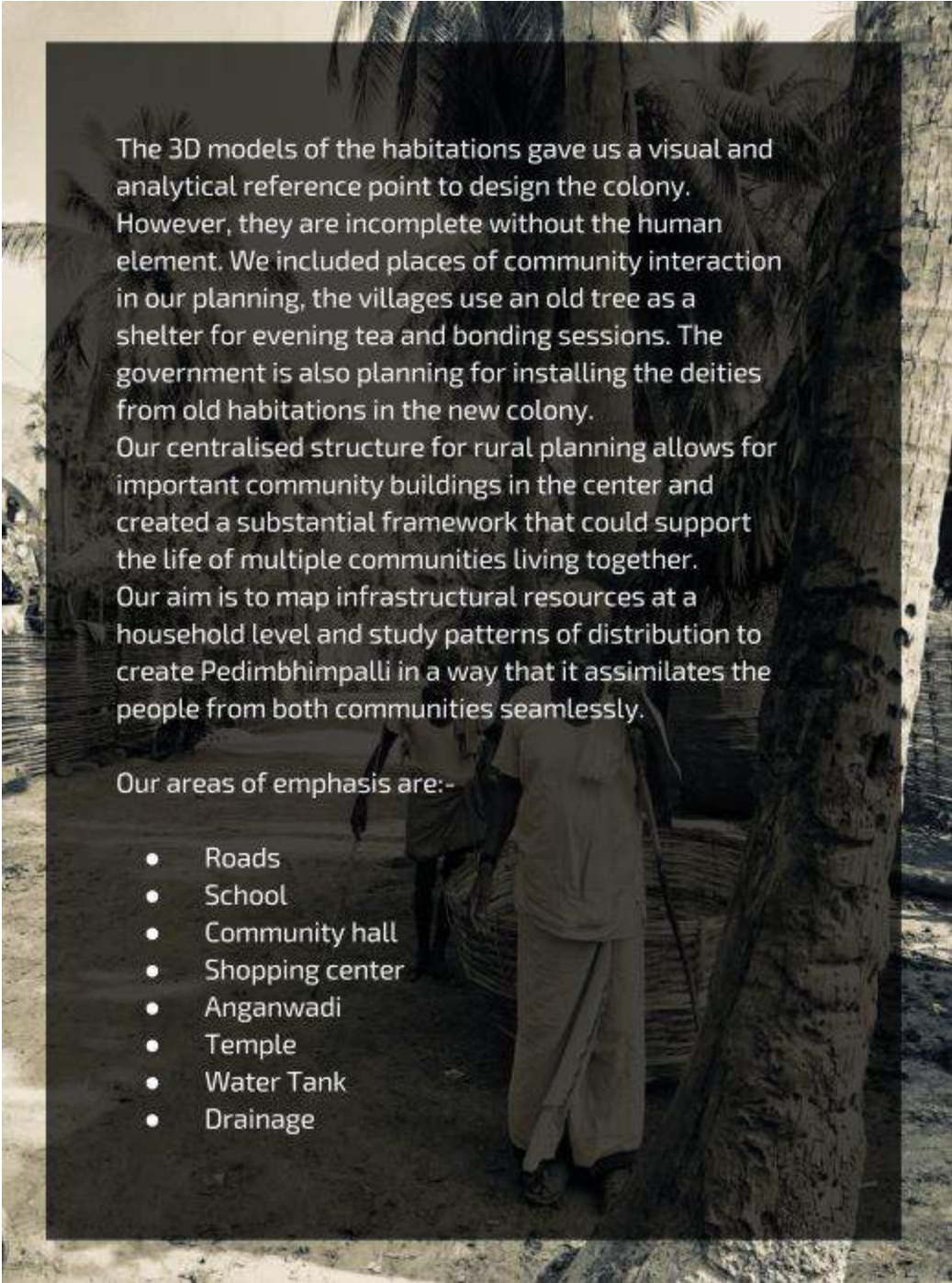
1. **Reachability:** Madepalli and Penkalupadu are close to Devipatnam (28 km from Rampachodavaram).
2. **Telecom Coverage / Internet Service Providers:** extremely limited coverage from BSNL
3. **Water:** No treated water
4. **Economic base:** Riverside agriculture based economy (maize, sometimes rice)
5. **Socialising base:** Center of village around school



*(Pictures from our visit to the villages in East Godavari)*

## Ethnographic Research

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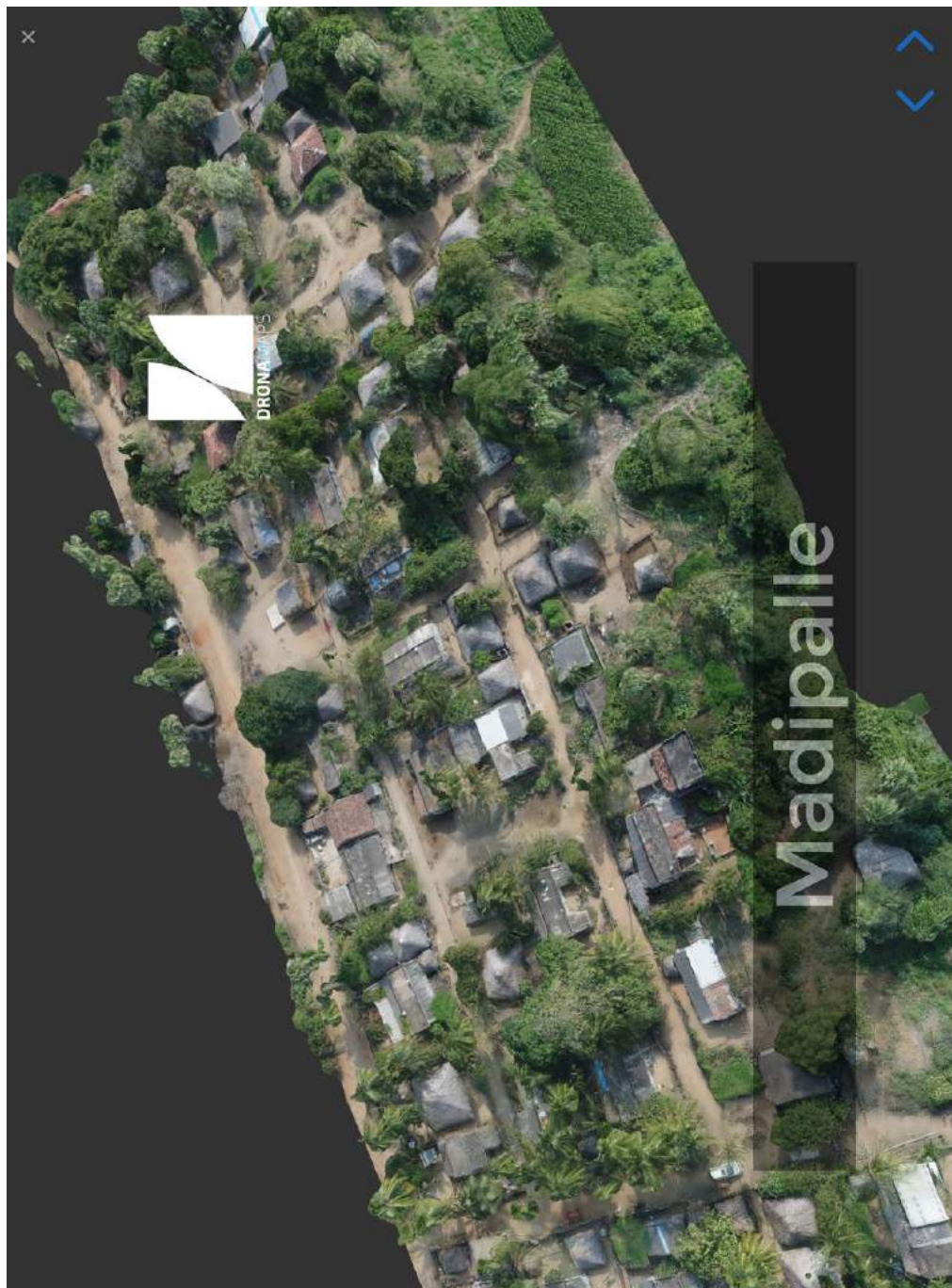
The 3D models of the habitations gave us a visual and analytical reference point to design the colony. However, they are incomplete without the human element. We included places of community interaction in our planning, the villages use an old tree as a shelter for evening tea and bonding sessions. The government is also planning for installing the deities from old habitations in the new colony. Our centralised structure for rural planning allows for important community buildings in the center and created a substantial framework that could support the life of multiple communities living together. Our aim is to map infrastructural resources at a household level and study patterns of distribution to create Pedimbhimpalli in a way that it assimilates the people from both communities seamlessly.

Our areas of emphasis are:-

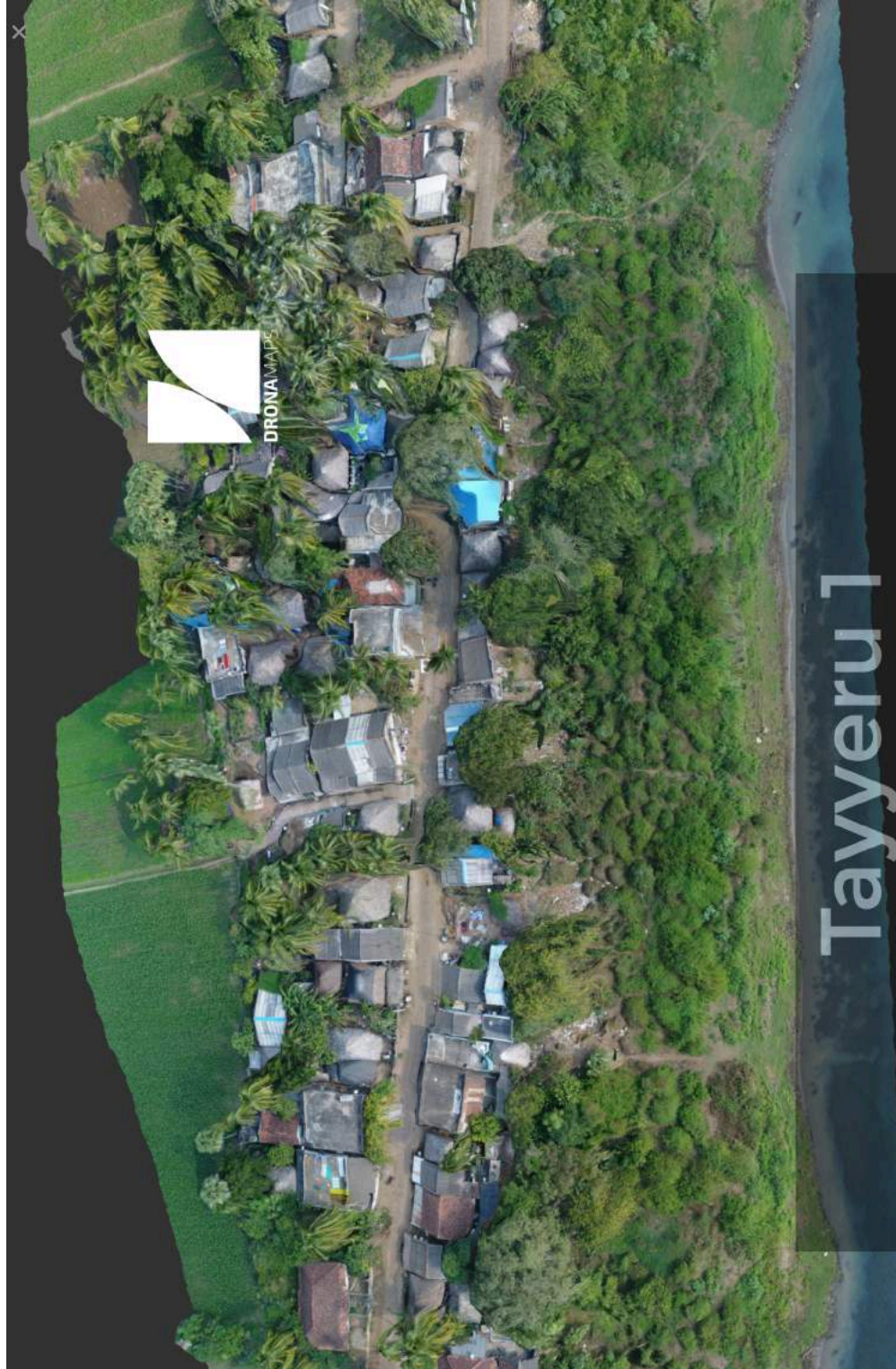
- Roads
- School
- Community hall
- Shopping center
- Anganwadi
- Temple
- Water Tank
- Drainage

## 3D Maps | Preserving The Original Habitations |

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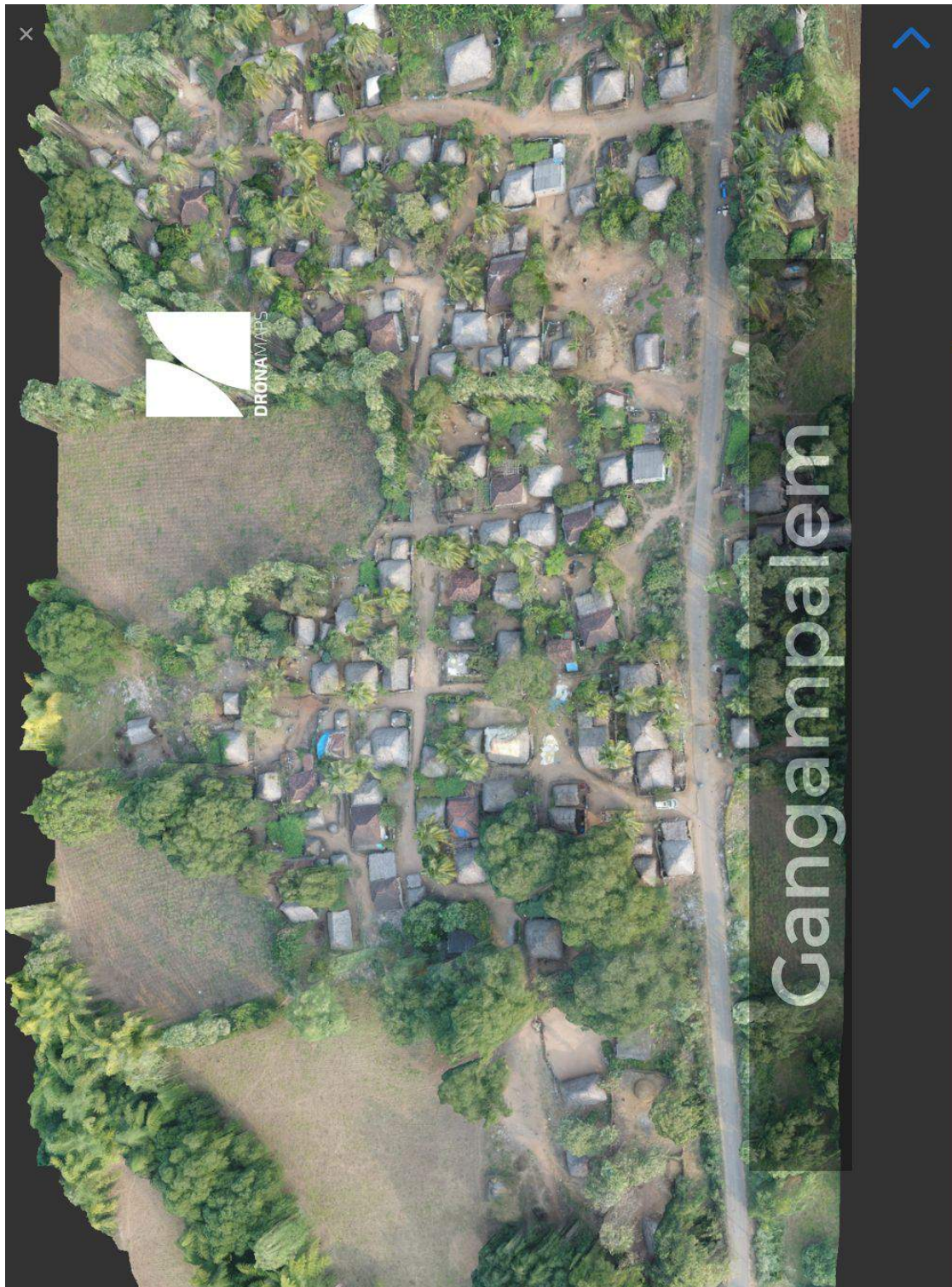








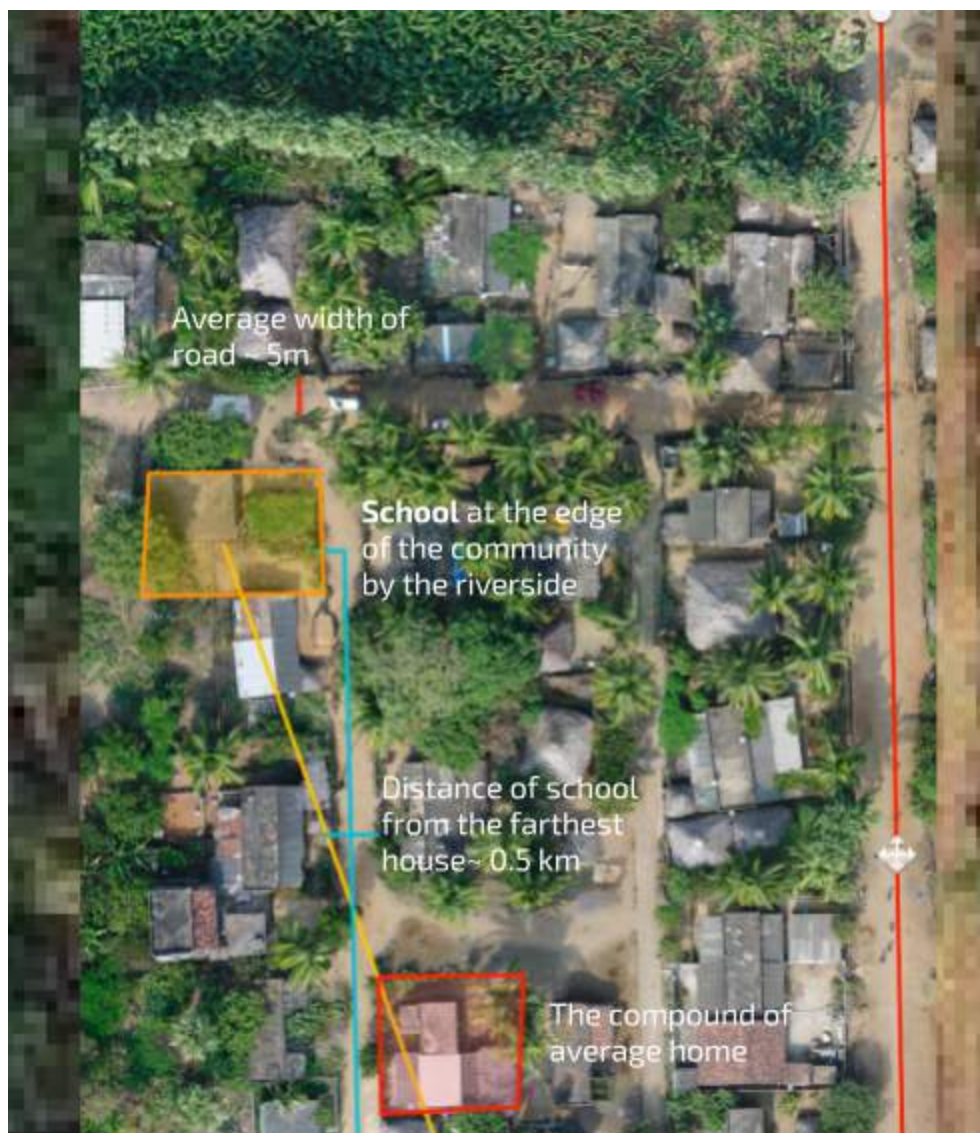




## Insights from the 3D Maps of |The Habitations|

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The old habitations like Madepalli have grown organically along the river bank. Important infrastructural elements like the school are at the edge of the village close to the river and farther from the main approach road. A similar pattern is followed in most villages. However, we are designing the colonies such that if the village is divided into four equal parts, all parts would have similar accessibility to the public infrastructure. Also, the roads are nearly three times wider (~12m versus the 5m in habitations).



## Getting to Know | Pedimbhimpalli |

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- **Number of beneficiaries:** 129 houses
- **How to reach Pedibhimpalli:**
  - From Rajahmundry Bhadrachalan highway, head towards Gokavaram, Pedibhimpalli is 10-12 km towards Indukuripeta
- **Telecom Coverage / service providers:** BSNL
- **Water:** Overhead Tank strategically placed at the highest point of contour on the site
- **Electricity:** Available
- **Economic base:** Agriculture based (riverside, maize, sometimes rice)
- **Possibilities in agriculture:** Cashew, mango, rice possible on pedibhimpalli site.
- **Internet subscribers:** Wired connection possible, wireless limited (it is possible to get an optical fiber connection from Gokavaram, only 10 km away)

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## Bringing | Pedimbhimpalli | Alive

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This is how we created the colony:



*(Orthomosaic- Pedibhimpalli-2)*

The Orthomosaic is processed based on the image data collected from high definition cameras mounted on the UAV. We also extracted 20cm contour from the data. Below is the image.



*(Contour map- Pedibhimpalli-2)*

Once, we had analysed the intricacies of the ground digitally, we started the CAD integration and planning process.



*(Plot outlines- Pedibhimpalli-2)*



*(Levelling Stage- Pedibhimpalli-2)*



*(2D plan of the colony- Pedibhimpalli-2)*



*(3D plan of the colony in context- Pedibhimpalli-2)*

## Benefits of using a 3D model for the design process:

- **Understanding of the site within the larger context** of its surrounding geography.
- **Ability to revisit digitally and retrieve authentic information.** Traditionally, site visits are a mandatory part of the design process, where architects and civil engineers take photographs to keep a log. Our models provide the ability to experience the site complete with granular analytics.
- **Access Points:** Measure and simulate key access points to the site.
- Maps **contours with precision.** This functionality allows for a well-informed planning of services like roads and water tanks in particular.
- Understand how the buildings and topography would react to **sun and shadows** and hence plan for better utilisation of daylight and possibly use solar energy.
- **Accurate locations of the natural features and local vegetation** allows the architect to make a choice of whether to **incorporate them as a part of the design** with a high level of precision unachievable by manual site surveys.
- **Modeling for ventilation** is a key factor in creating a home for hot and humid climate so that we also optimise for energy usage. The 3D model supports planning for the movement of air through the site.

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## Making Pedimbhimpalli a Home | The Masterplan |

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The habitations of Madipalle and Penkalupadu would find a home in the colony of Pedimbhimpalli-2. We visited these habitations to make their 3D models. To serve the way of life in the habitations, the colony has the more integral community buildings in the center for easy access from all points.

The masterplan of the colony has been carefully planned with an attention to detail--the water tank has been placed on the highest point of the contour and the drains designed to lead the rainwater to the pond. While the pond itself is at naturally the lowest point in the contour to ensure that it is filled with water for a large part of the year.



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## Making Pedimbhimpalli a Home | The Houses |

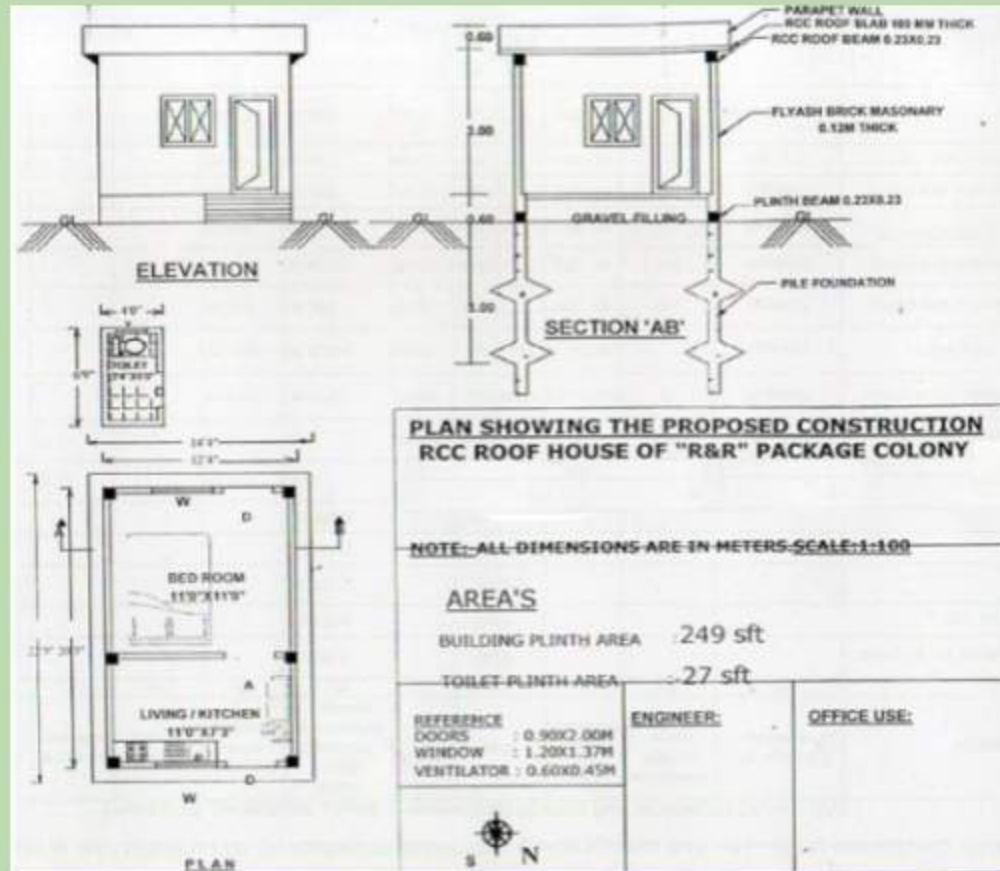
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The government is providing people (House 1) as a basic model, where they get a plinth area of 249 square feet. However, the people also get an option to add more funds to government funds and build any of the houses (2 & 3). This gives the people the ability to customise their own home at their own expense and allows the colony to be more symbolic of their identity and choices.



*(House 1, budget: 2,30,000 INR)*

The basic house includes a living room, a bedroom and a kitchen in the layout. A toilet is built separately. According to our recommendations there is a possibility to cut costs and optimise designs even in this very basic structure. We would discuss more about this aspect later in the report.

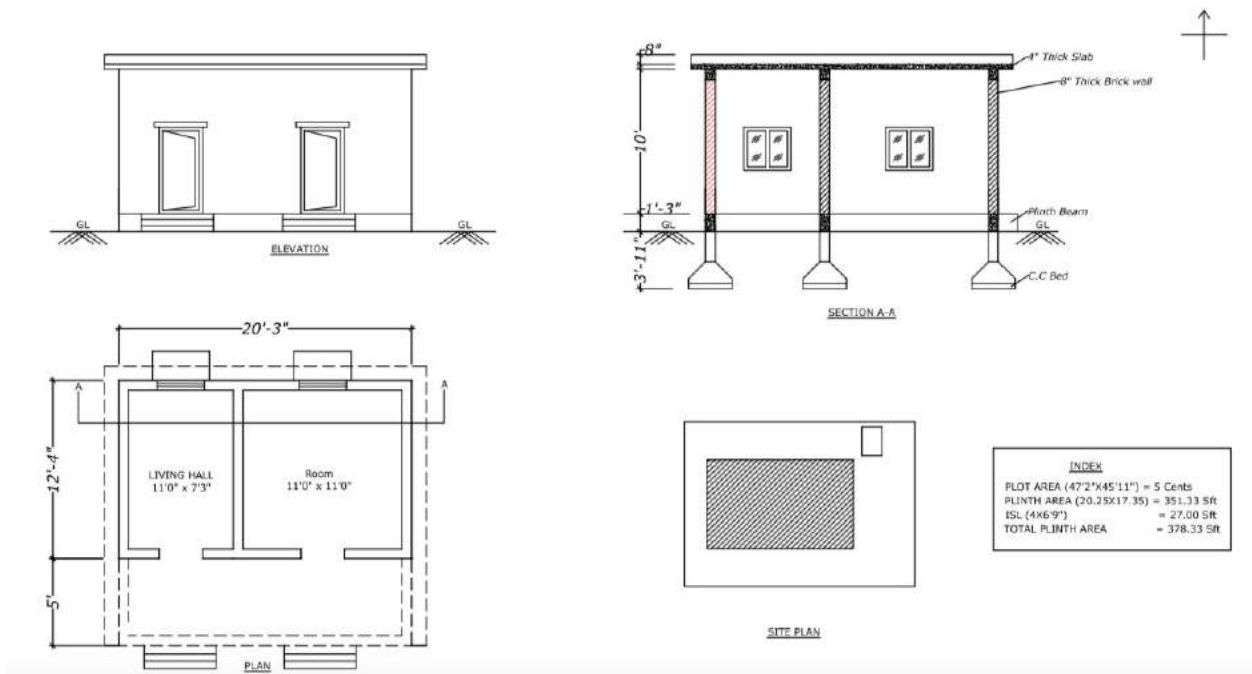


Plans for House-1

In our ethnographic study, we discovered that one of the elements that dissuade people from moving into these houses is the lack of identity or character that they exhibit. If we manage to give the people the ability to customise the house within the same budget, it would be a more enticing proposition and could persuade them to leave their old habitations and move. The following pages showcase the plans for the house (2&3) where people can contribute to the budget of the house and build a dwelling more suitable for a large family.



(House 2, budget: 4,00,000 INR)



(Plan for House 2, budget: 4,00,000 INR)

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## Making Pedimbhimpalli a Home | The Amenities |

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A community is made by more than just the houses. There are two elements to it- the physical spaces and the network of people. While designing a community we must keep in mind that our physical spaces facilitate the network of people and their interaction. The center of Pedimbhimpalli have been assigned the community buildings to make them accessible from all four parts of the colony. In addition, the overhead tank is placed close to these primary infrastructural elements to facilitate the distribution of water.

Our design for the colony complements the thought process of the governing bodies. We have aligned our physical models to the philosophical elements that they intend to infuse the buildings with. For instance, the school is designed to be in Vedanta style and would have internet connectivity along with functional learning aids.



*(Model for Vedanta school)*



*(Model for Anganwadi)*

*Elaborating on the human elements in the physical structures of anganwadi and the school:*



Inspired by Vedanta Foundation –  
Anganwadi Models under CSR

- Colorful and attractive
- Child friendly construction
- Engaging children with Digital Teaching Learning

Materials.



Complete with Building as Learning Aid (BaLA)

- Using the anganwadi building itself a learning aid
- Innovative models to motivate kids enrollment and retention
- More interactive and exploratory



- Support for Peer-to-Peer Learning Structure
- Enabling minimum learning abilities by Vandemataram Foundation



(The site of community building and commerce: *shopping center at the ground floor and community hall on top*)



(Model for overhead water tank placed at the highest point of contour on the site to facilitate judicial distribution of water through the colony)



*(Insight from Ethnographic study: The villagers wish to place the deities from their habitations in the colony temple. )*

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## Vision for | PedibhimPalli | Innovation incarnate

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Seldom in one human life, one gets a chance to design the habitat of a community with over 129 households from scratch. The rehabilitation and resettlement of displaced communities is a noble goal and one for which our company- DronaMaps decided to go the extra mile. In this section we would like to propose cost effective and innovative solutions for Pedimbhimpalli- the village symbolising the future of India.

### Our Inspiration



Laurie Baker (1917- 2007)

A British Born Indian architect awarded a Padmashri for his contribution to his field. Due to his social and humanitarian efforts to bring architecture and design to the common man, his honest use of materials, his belief in simplicity in design and in life, and his staunch Quaker belief in non-violence, he has been called the "**Gandhi of architecture.**" Post Independence, Baker chose to stay back and contribute to the foundations of an independent India centered in its villages.

## Architectural Design Recommendations

**CargoPods**, our Architectural design partners specialise in human centred and innovative design of spaces. The idea is to create timeless design that stays young with age. The form follows the function. They take functionality as non-negotiable and enthuse it with a *raison de etre* to make the space meaningful for the people.

In the spirit of Laurie Baker's vision for rural development. We gratefully take this chance to propose some changes to the masterplan and architectural design of the houses. The purpose is to include some **intelligent cost saving measures** that also ensure that the rehabilitation and resettlement is into a colony that is **aesthetically and functionally** ready to be home.

- **Filler slabs** ( reduces ceiling cost by nearly 50% and is aesthetically pleasing )
- **Utilising the brick texture** ( aesthetically pleasing and saves cost on plaster, plus the insulation needs would be fulfilled by strategic placement)
- **Thatched roof porch area using local sourced materials on the demand of villagers** (an insight from our ethnographic study). The increased cost can be accommodated within the savings from the changes we made above.
- Creation of **Microclimates** (vegetation, wind, and water body optimisation)
- Designing **buffer areas within the masterplan for better ventilation.**
- Adding vents in the house for **cross ventilation.**



## Mobile Infrastructure

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### The Clinic in a Can | Radiation Proof Telemedicine System within budget|

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Refurbishing old shipping containers provides an excellent base to build sturdy and mobile structures that would be a critical component of our ambition to create a village for the future. Not only is this environmentally friendly, these structures can easily be fitted with latest technology and provide the option of creating a fleet of structures that are mobile and act as a shared resource between a couple of colonies.



*(Clinic in a can: insulated and possible to move if needed)*



*(Outer view: Equipped with shed and a seating area)*



*(Interiors: Steel cabinets by medical standards, exam table, telemedicine unit with screen, camera, Wifi enabled, easily cleanable wall panels, vandalism proof, )*

## Benefits of using Refurbished Containers:

- The cost is 12 Lakh INR (not accounting for tax and transportation costs)
- **Telemedicine equipped** and it is possible to consult with city doctors to seek informed treatment options.
- Mobile and **can be shared between closely spaced colonies**. Thereby, saving cost.
- Steriliser included
- Integrated diagnostic wall unit
- Vandalism proof, water proof, and impact resistant
- Can be disinfected with hospital grade cleaners
- Can be made Solar Powered with an investment of 1.5 Lakh INR.

## Mobile Veterinary Hospital | Shared Cost in Colonies | Within Budget



Every colony has a proposed veterinary hospital with a budget of 12,20,000 INR. The cost of a refurbished shipping container would be a fraction of this amount and it would be fitted with state of the art technical equipment. The entire assembly can travel and be shared by a couple of villages to create a sharing economy effect. Benefits of using refurbished containers as veterinary hospital: Cost - approximately 6 Lakh INR (not accounting for tax and transportation costs) & Mobile and can be shared between closely spaced colonies. Thereby, saving cost.

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## Future Scope | The Conclusion

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“The arrival of basic knowledge through the publication of new maps causally affects the discovery of new opportunities and entrepreneurship in the private Sector. By opening the “black box” of mapping as an economic activity, it is possible to understand the role of public investments in basic knowledge on both industry performance and entrepreneurship. Smaller firms benefited more than three times as much as incumbents from new mapping information. “

- Abhishek Nagaraj (PHD MIT SLoan, Assistant Professor, Haas Management of organisations| Berkeley|

Post the successful completion of this pilot, and having taken this chance to familiarise ourselves with the wonderful people of East Godavari. We are excited to create 3D maps for 184 submerging habitations by October 2018, thereby, creating a virtual repository of these places as they existed for generations to come.

It would be our honor to provide our 3D technology and analytical insights drawn from it to aid the planning of the new colonies. Through this pilot we have provided a blueprint of our capabilities and how we fit with the existing machinery of the government. We recognise that it is a unique opportunity to part of this project for the successful rehabilitation and resettlement of people. We offer our services complete with informed design of the colonies, blockchain integrated land records, and innovative design elements that can truly transform Pedibhimpalli into a smart village capable of representing the future of the villages in our country.

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## The Verdict | by the DM

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