Human-Robot Collaboration for Disaster Relief

Graduation Progress Week 1.2(.1)

Graduation Studio Extraterrestrial Architecture MSc 3 | Maria Dumitrache

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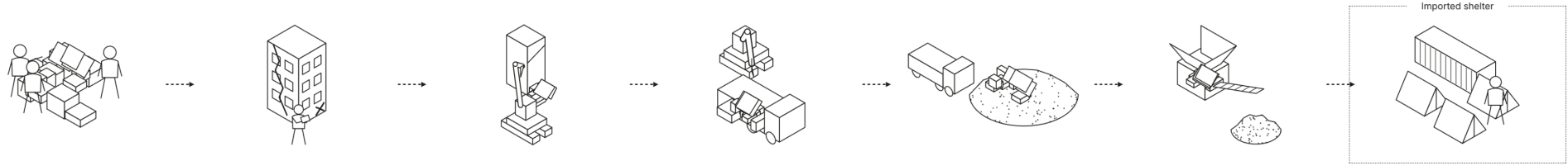
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4. PROJECT PLAN

Current versus proposed approach

A - CURRENT APPROACH

Excavators, trucks and manual labour. Linear: debris leaves the site, shelter arrives from outside.



01 Search & rescue
Rescue teams search the rubble by hand; drones map the site from above.

02 Damage assessment
Engineers inspect buildings one by one and mark them for repair or demolition.

03 Demolition
Excavators pull down unsafe structures, with operators close to unstable debris.

04 Loading
Mixed rubble is loaded onto trucks, mostly unsorted.

05 Hauling
Trucks haul the rubble to temporary debris sites or landfill.

06 Partial recycling
Where programmes exist, part of it is crushed for reuse (e.g. UNDP in Türkiye, 2023).

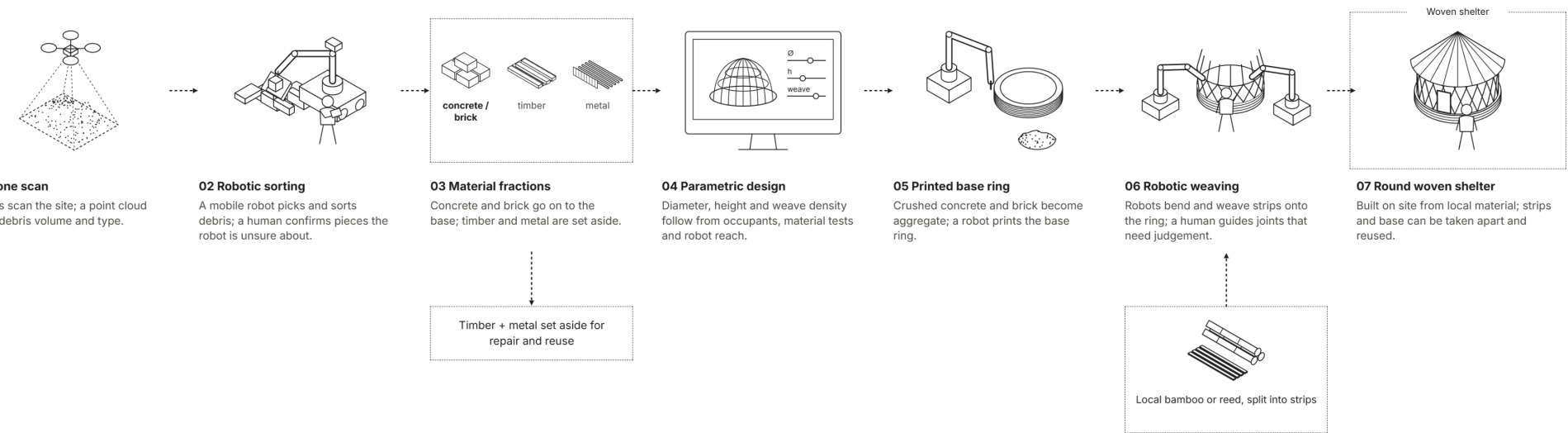
07 Temporary shelter
Displaced people move into tents and containers brought in from outside.

Material flow: site → landfill · Shelter flow: from outside → site

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B - PROPOSED ROBOTIC WORKFLOW

Debris is sorted on site. The mineral fraction becomes the base, local bamboo the woven envelope. Humans stay in the loop.



01 Drone scan
Drones scan the site; a point cloud maps debris volume and type.

02 Robotic sorting
A mobile robot picks and sorts debris; a human confirms pieces the robot is unsure about.

03 Material fractions
Concrete and brick go on to the base; timber and metal are set aside.

04 Parametric design
Diameter, height and weave density follow from occupants, material tests and robot reach.

05 Printed base ring
Crushed concrete and brick become aggregate; a robot prints the base ring.

06 Robotic weaving
Robots bend and weave strips onto the ring; a human guides joints that need judgement.

07 Round woven shelter
Built on site from local material; strips and base can be taken apart and reused.

Material flow: stays on site · Shelter built where people are, from debris and local fibre

NATURAL DISASTERS

Nepal Flash Floods



A drone view shows rescue workers inspecting damaged structures following flash flooding along the Trishuli River in the Devighat area of Nuwakot district, Nepal, on August 29, 2026

1. LOCATION CHOICE

1.1. Description and Problem Statement

Bhote Koshi flood at Syabrubesi, Nepal

Event Data

A major flash flood entered Nepal through the Bhote Koshi River at approximately 9:00 AM on 26 August 2026, causing significant loss and damage across Rasuwa, Nuwakot and Dhading districts. (Nepal Flash Flood 2026 - Nepal | ReliefWeb, n.d.)

The cause of the flood remains under investigation, with authorities assessing the possibility of a glacial lake outburst flood (GLOF) or another upstream hydrological event. (India, n.d.)

1,453 people reported dead
5,179 people still missing
13,795 people have been rescued
1,109 displaced people remain in 21 displacement centers

Context

By official count, the Bhotekoshi flood now the deadliest flood in Nepal's modern record.

The Rasuwa corridor floods again and again. Between 2022 and 2026, five significant flash floods hit the Rasuwa district. In 2025, the Lhende-Bhote Koshi river system flooded twice, on 8 and 30 July. Together, the floods killed at least 20 people. The cause of the July 2025 event was different: a supraglacial lake on Tibet's Purepu Glacier rapidly drained, causing a flash flood.

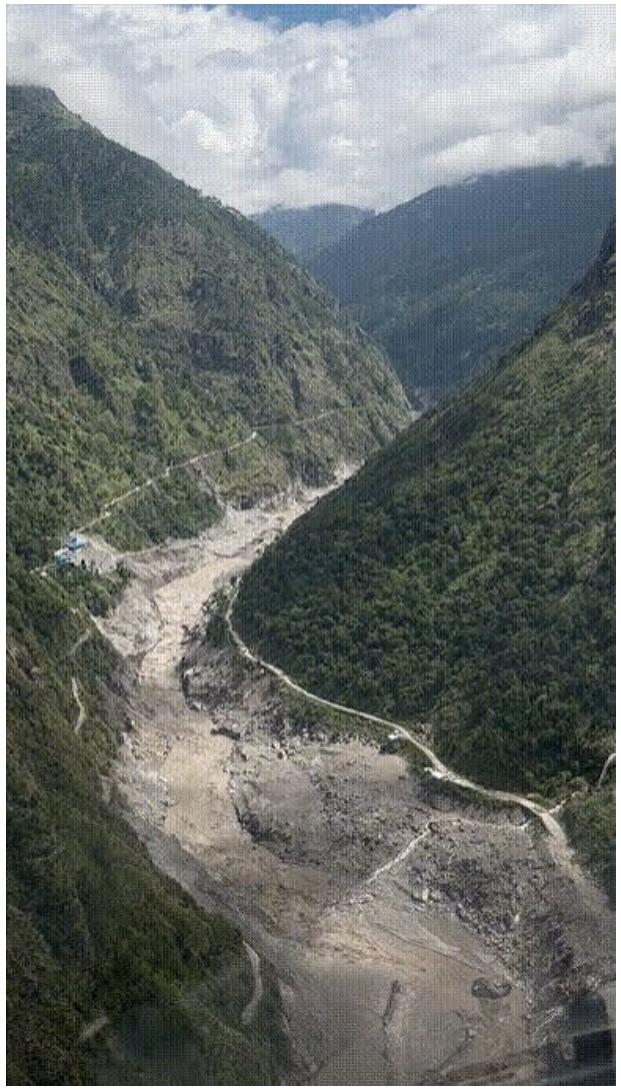




Syabrubesi, Napal

1. LOCATION CHOICE

1.1. Description and Problem Statement

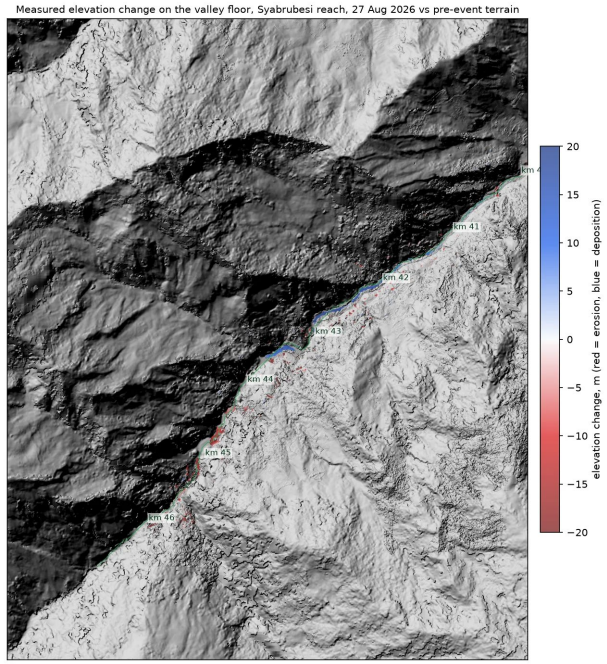


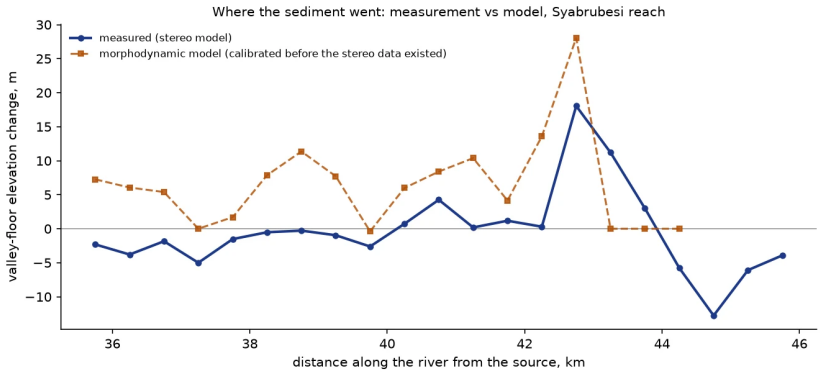
1. LOCATION CHOICE

1.2. Mapping the location

Bhote Koshi flood at Syabrubesi, Nepal

Generating a 3D model from existing data using geopera resources. (The Bhote Koshi Flood in Half-Metre Relief: What the Stereo Data Changed, n.d.)





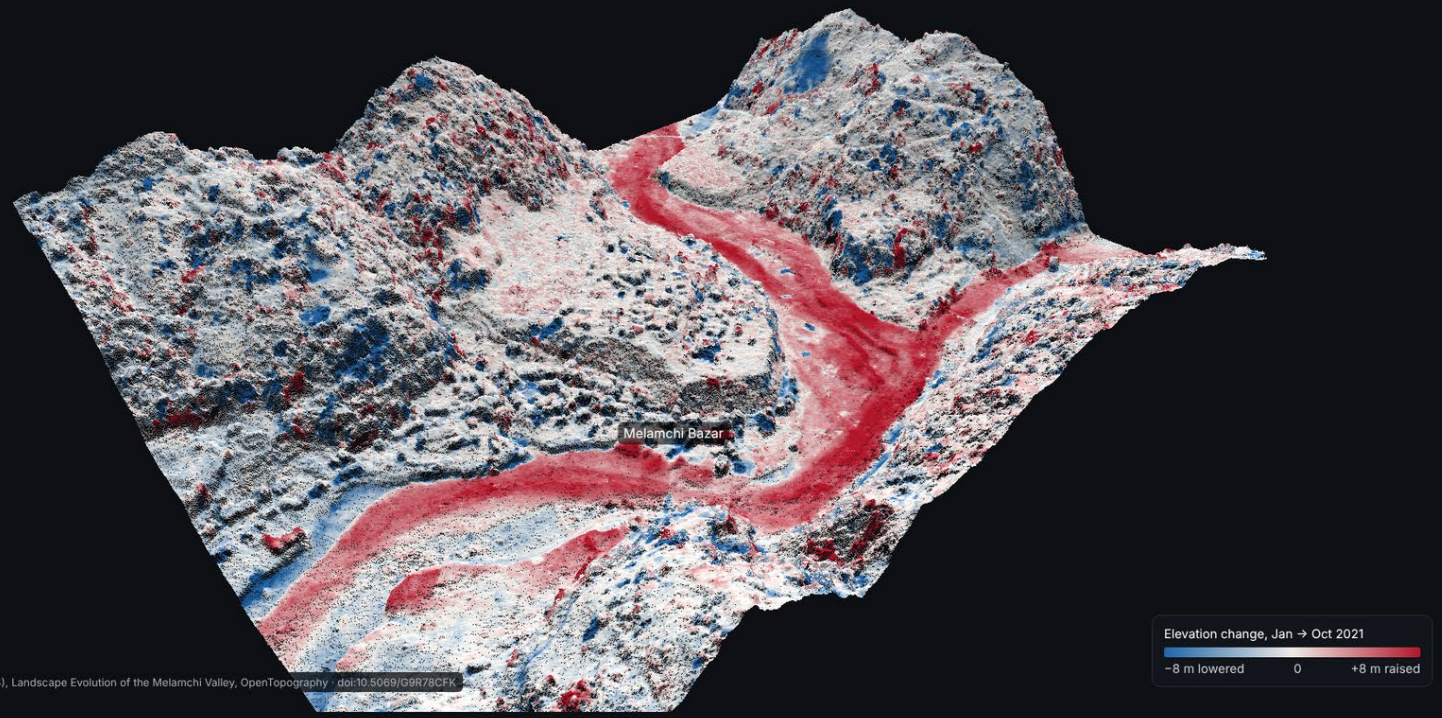
1. LOCATION CHOICE

1.2. Mapping the location

Melamchi Bazar, Nepal — 2021 flood

1 m point cloud from Pléiades stereo · 1.92 M points per survey

October 2021 · after the flood



Before · January 2021



DATA

Event	Melamchi debris flood, 15 June 2021, Sindhupalchok, Nepal
Sensor	Pléiades stereo, 0.5 m imagery → 1 m DSM (photogrammetry)
Surveys	Jan 2021 (pre) · Oct 2021 (post)
Area	1.2 × 1.6 km around Melamchi Bazar
Points	1.92 M per survey (1 m grid)
CRS	WGS 84 / UTM 45N (EPSG:32645)

PROCESSING

Alignment	Median offset between surveys (≈0.8 m) removed
Colour	Elevation change, ±8 m diverging scale
Display	Point cloud, vertical ×1.5, NW hillshade

READING THE IMAGE

- Red band = valley floor raised by flood sediment through and beside the town; blue = banks, buildings and trees removed.
- Surfaces include buildings and vegetation, so changes under ~1–2 m are partly noise.
- Source: Chen, C. (2024). Landscape Evolution of the Melamchi Valley, Nepal (2014–2024). OpenTopography. doi:10.5069/G9R78CFK

Melamchi Bazar flood — 1 m point cloud, before & after (2021)

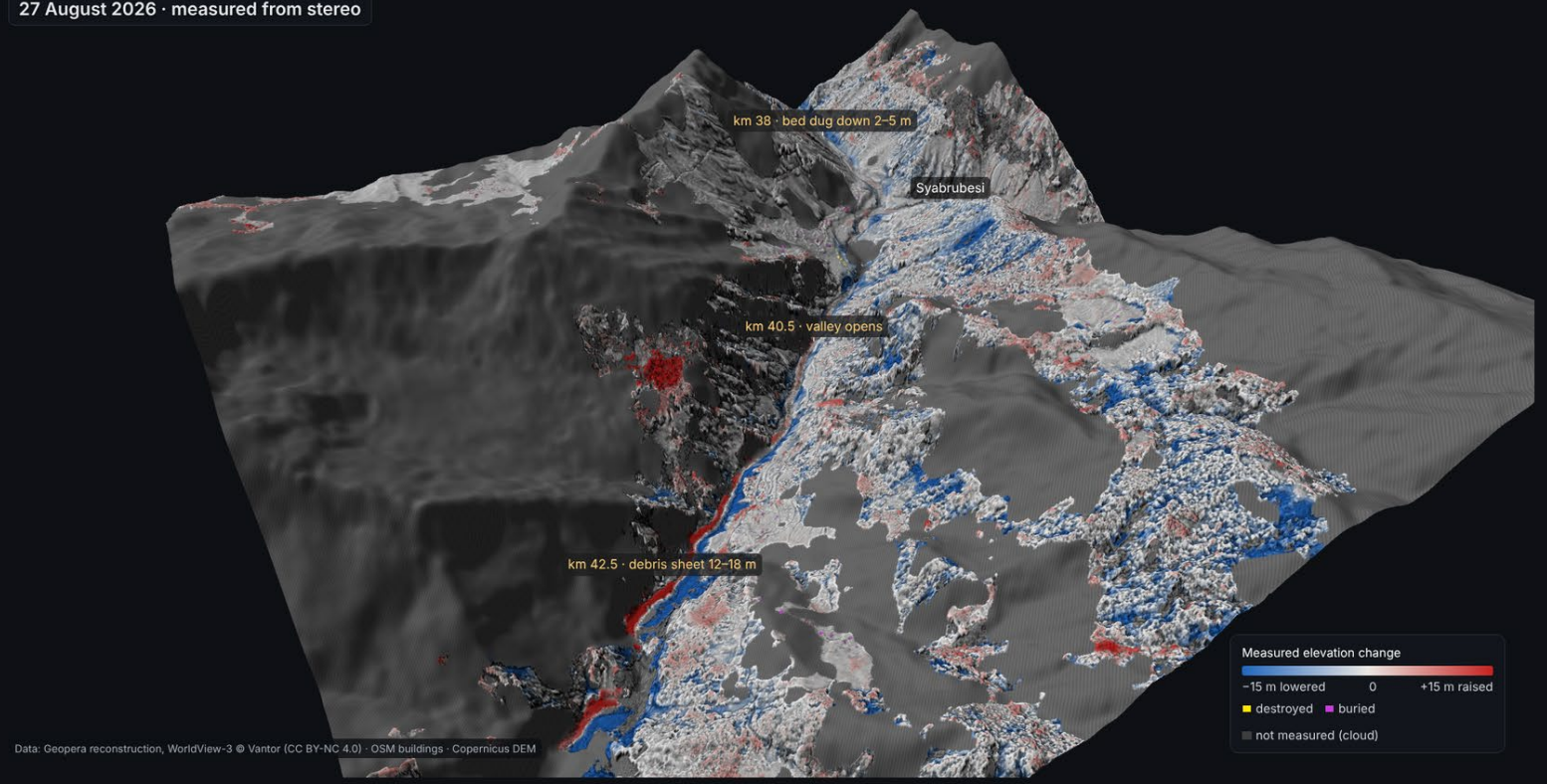
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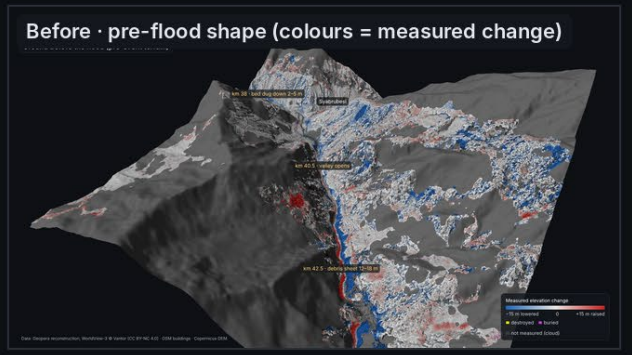
1.2. Mapping the location

Bhote Koshi flood, Syabrubesi — 26 Aug 2026

Half-metre WorldView-3 stereo surface vs pre-event terrain

27 August 2026 · measured from stereo



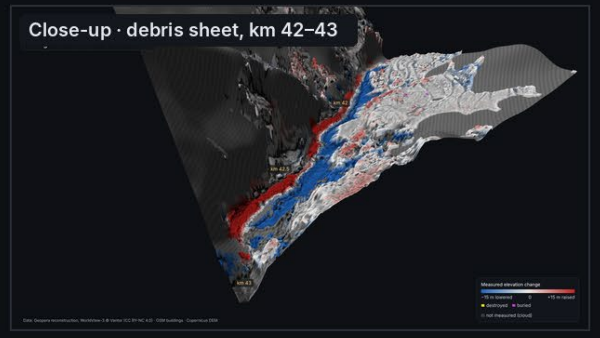


DATA

Event	Bhote Koshi outburst flood, 26 Aug 2026, Rasuwa, Nepal
Sensor	WorldView-3 in-track stereo, 27 Aug 2026 (0.34 m native)
Products	0.5 m DSM · 2 m elevation change · 2 m uncertainty
Accuracy	±1.45 m (σ) on stable ground
Measured	≈42% of overview, 57% of close-up (rest under cloud)
Fill	Copernicus GLO-30 where not measured (hatched grey)

PROCESSING

Overview	5.3 × 5.3 km, 5 m mesh, 1.3 m texture
Close-up	1.2 × 1.2 km, 1 m mesh, 0.5 m texture
Colour	±15 m; fades to grey below ~2σ
Buildings	OSM census: yellow destroyed, magenta buried



KEY FINDINGS (GEOPERA STEREO VS EARLIER IMAGE-BASED MODEL)

- Above km 40.5 the flood dug its bed down 2–12 m; the 12–18 m debris sheet lies at km 40.5–43.6; a 13–21 m trench is cut below it.
- The earlier image-based "new sediment" layer was mostly erosion: 56% of flagged pixels were lowered, 2% raised.
- Census file: 36 destroyed + 129 buried; Geopera's article reports 27 destroyed (vetted figure).
- Data: Geopera reconstruction, WorldView-3 © Vantor (CC BY-NC 4.0); OSM; Copernicus DEM.

1. LOCATION CHOICE

1.2. Mapping the location

Bhote Koshi flood at Syabrubesi, in half-metre relief

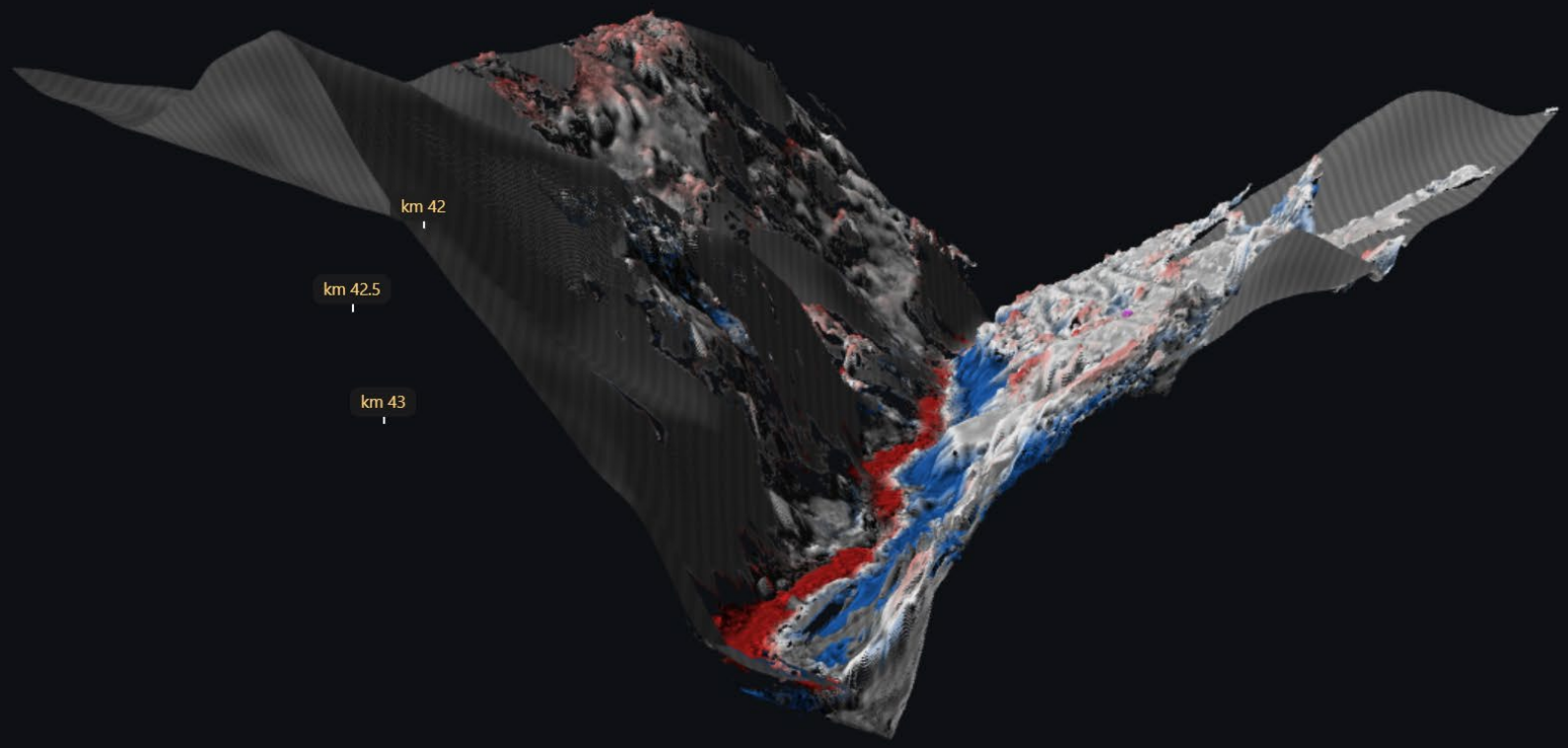
Hide

Ground surface measured from WorldView-3 stereo images taken 27 Aug 2026, the day after the flood. Each point is coloured by how far it moved up or down compared with the ground before the flood. Data: Geopera reconstruction (Vantor WorldView-3, CC BY-NC 4.0).

WHAT CHANGED FROM THE EARLIER MODEL

- **Real elevation change instead of an image guess.** The earlier model showed 30 m terrain from before the flood, with colours from comparing two images. This one measures the ground surface after the flood at 0.5 m.
- **The orange "new sediment" was mostly erosion.** Of the pixels it flagged, **56%** were actually lowered (scoured banks) and only **2%** were raised. Switch to *Earlier model* to compare.
- **The main deposit lies outside the earlier window.** The 12–18 m debris sheet sits at river km 40.5–43.6, below Syabrubesi. Above town the flood dug its bed down by 2–12 m.
- **Buildings can be counted one by one.** Destroyed and buried buildings are marked from the building census.

Limits ▾



Measured elevation change (m)

−15 lowered 0 +15 raised

not measured (cloud)

building destroyed

building buried

building probably intact (relief view)

Overview 5.3 km | Debris sheet 0.5 m | Measured change | Relief | Earlier model | Surface | Points

Before ground before flood — 27 Aug 2026 (stereo) After ▶ Morph

Vertical × 1.0 Point size

© Vantor (WorldView-3) via Geopera, CC BY-NC 4.0 · OSM buildings · Copernicus DEM

2. POSITION: HUMAN-ROBOT COLLABORATION

Position: Human-Robot Collaboration

- opted for human-robot collaboration
- design from shelter, later expand to large scale
- leave material sourcing as conceptual
- *in-depth elaboration: PARAMETER INFLUENCED DESIGN + ASSEMBLY USING ROBOTIC TECHNIQUES*

... because/in order to (argument/defense):

1.**(human-robot, not robot)** protect heritage practice by continuation of craft

2.**(human-robot, not human)** increase speed of construction, lower injury risk, lower cost (?)

3.**(parametric/computational methods)** predict outcome, maximize material use efficiency

3. CASE STUDIES INSIGHTS

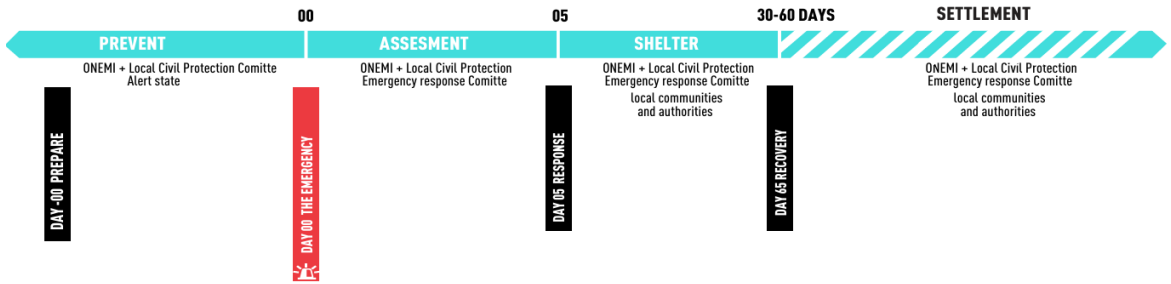
Position: Human-Robot Collaboration

Master Graduation Thesis of Marco Galli, 2018:

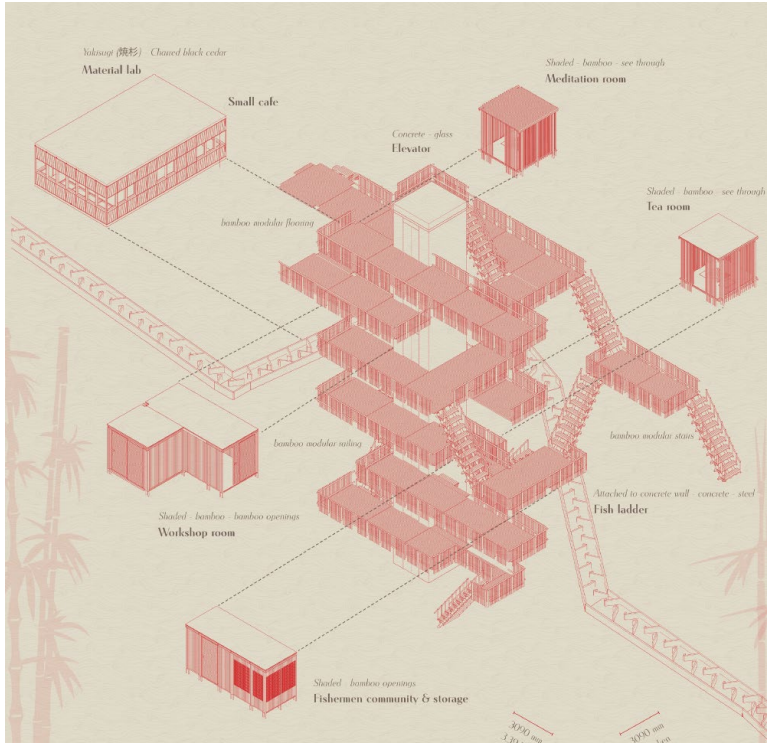
- **growth** from singular shelter units to assembly
- synthesis on disaster response and shelter design principles
- fully robotic assembly of one architectural unit “Pack” of robots with specific building and fabrication tasks. (non-applicable)
- “network programming” between the units, system planning with **evacuation routes as starting point**
- **project planning workflow**

Master Graduation Thesis on Flood Control Infrastructure on Arakawa River Basin by Sodaba Khalili, 2025:

- ecological considerations mapping
- infrastructure map, diagram DOWNSTREAM -what happens along the river
- multiple lens, including social around the fishing practice: yearly cycle of events and fluctuations in the fishing season and Japanese culture
- modern optimized vernacular design for material use



Risk management > Disaster risk reduction-oriented settlement > Sustainable projects *(Marco Galli. 2018)*



(Sodaba Khalili. 2026)

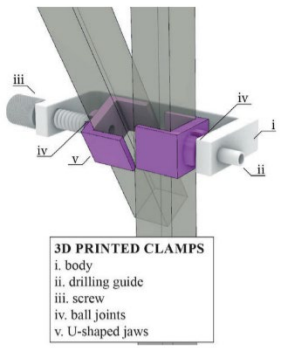
3. CASE STUDIES INSIGHTS

Position: Human-Robot Collaboration

TimberProxy – EPFL, 2025:

H-R ideation small scale > scanning/digitalization > 2 x R construction 1:1

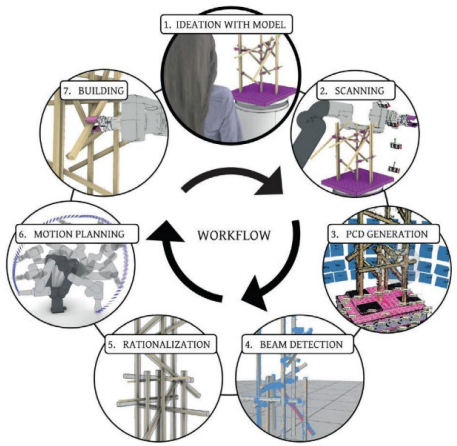
- possibility to implement similar workflow, but where the plan is set for HRC instead of 2 robots



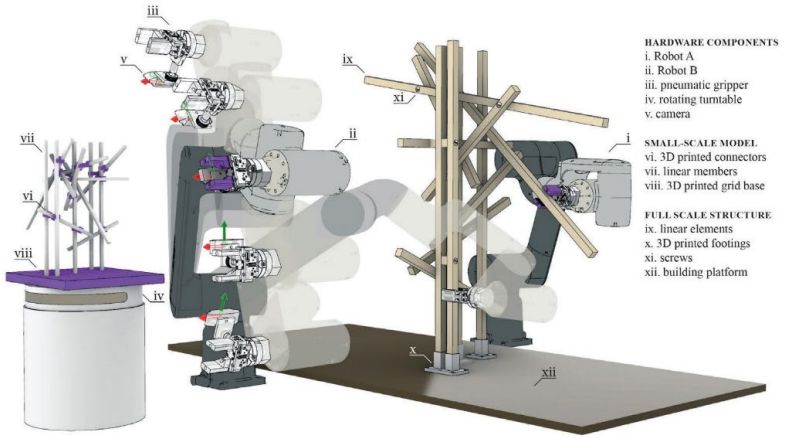
3 Photograph of all materials used in the iterative design-fabrication process.

4 Custom 3D-printed clamp designed to simplify drilling operations

5 Construction kits: (a) LEGO, (b) spaghetti, (c) Betzold Geometrie-Steckbaukasten, (d) K'nex, (e) Mola Structural Kit, (f) Geomag and (g) 1001 Hütten.



7



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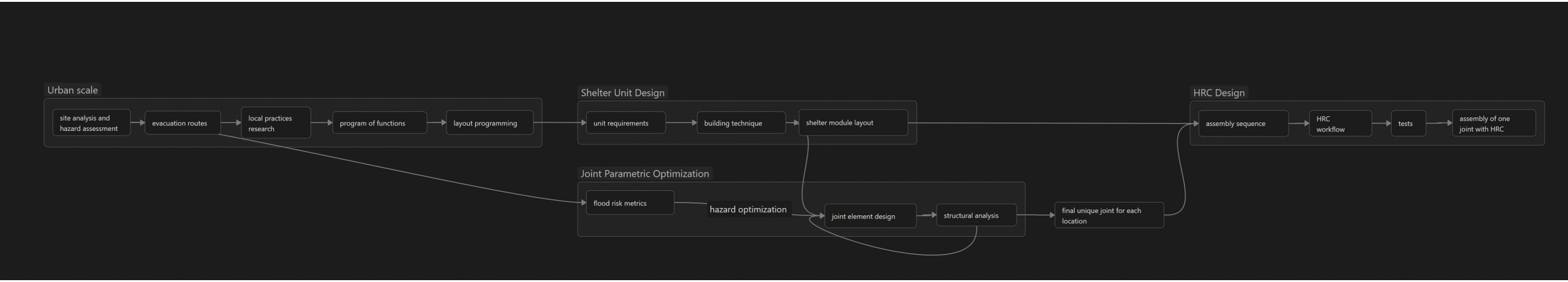
6 Overview of TimberProxy materials: hardware components (i-v); small-scale proxy (vi-viii); full-scale structure (ix-xii).

7 TimberProxy interactive workflow from human actions to robotic instructions

4. PROJECT PLAN

DESIGN STRUCTURE DRAFT
Design stages and substages

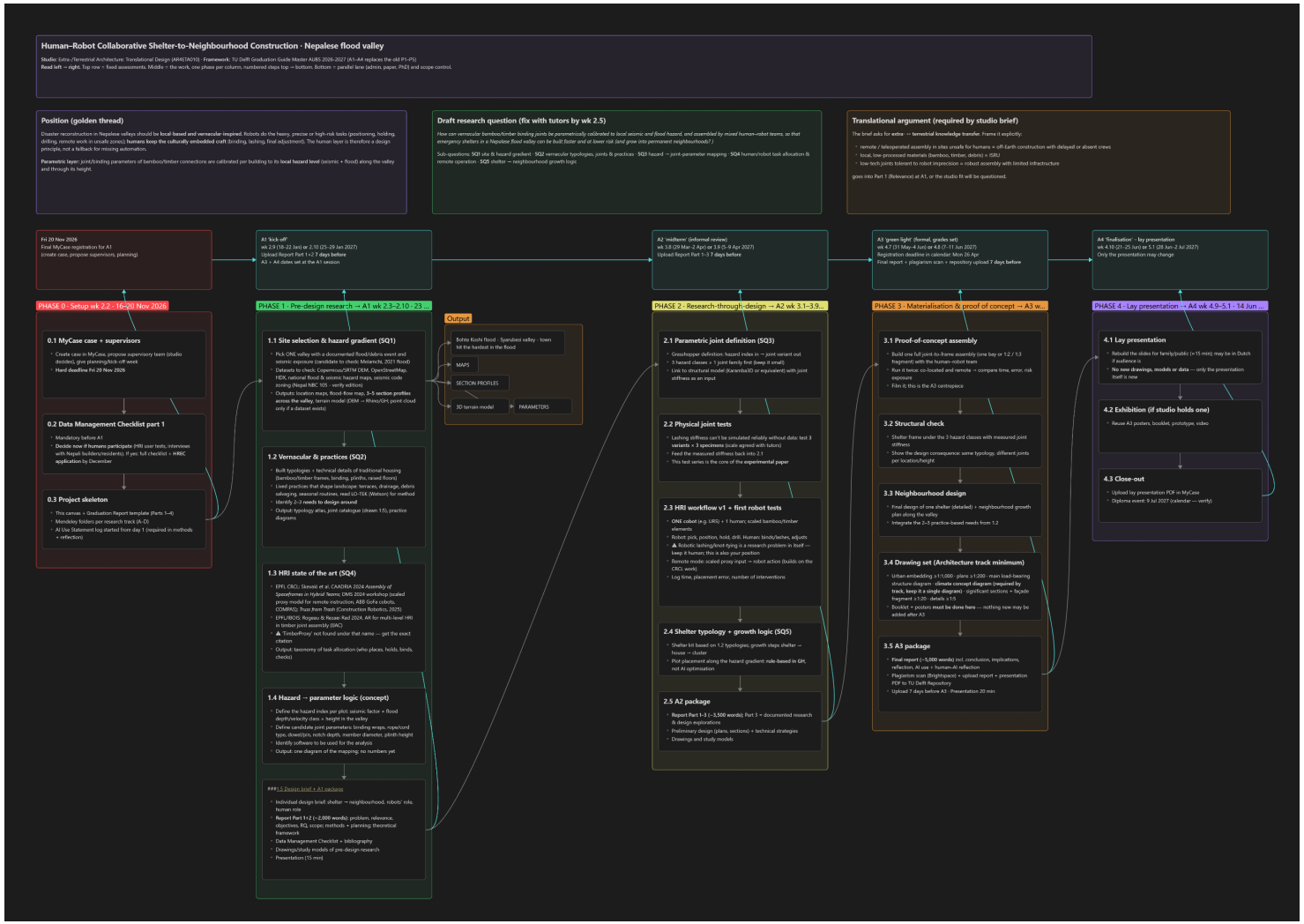
Urban scale – site analysis > and large-scale urban plan
Shelter unit design – requirements + layout + detailing
Joint parametric design – selection of 1 joint design and parametrizing for structural analysis
HRC design – plan for HRC assembly and testing a joint with one robot



4. PROJECT PLAN

STRUCTURE
Per delivery checkpoint (A1-A4)

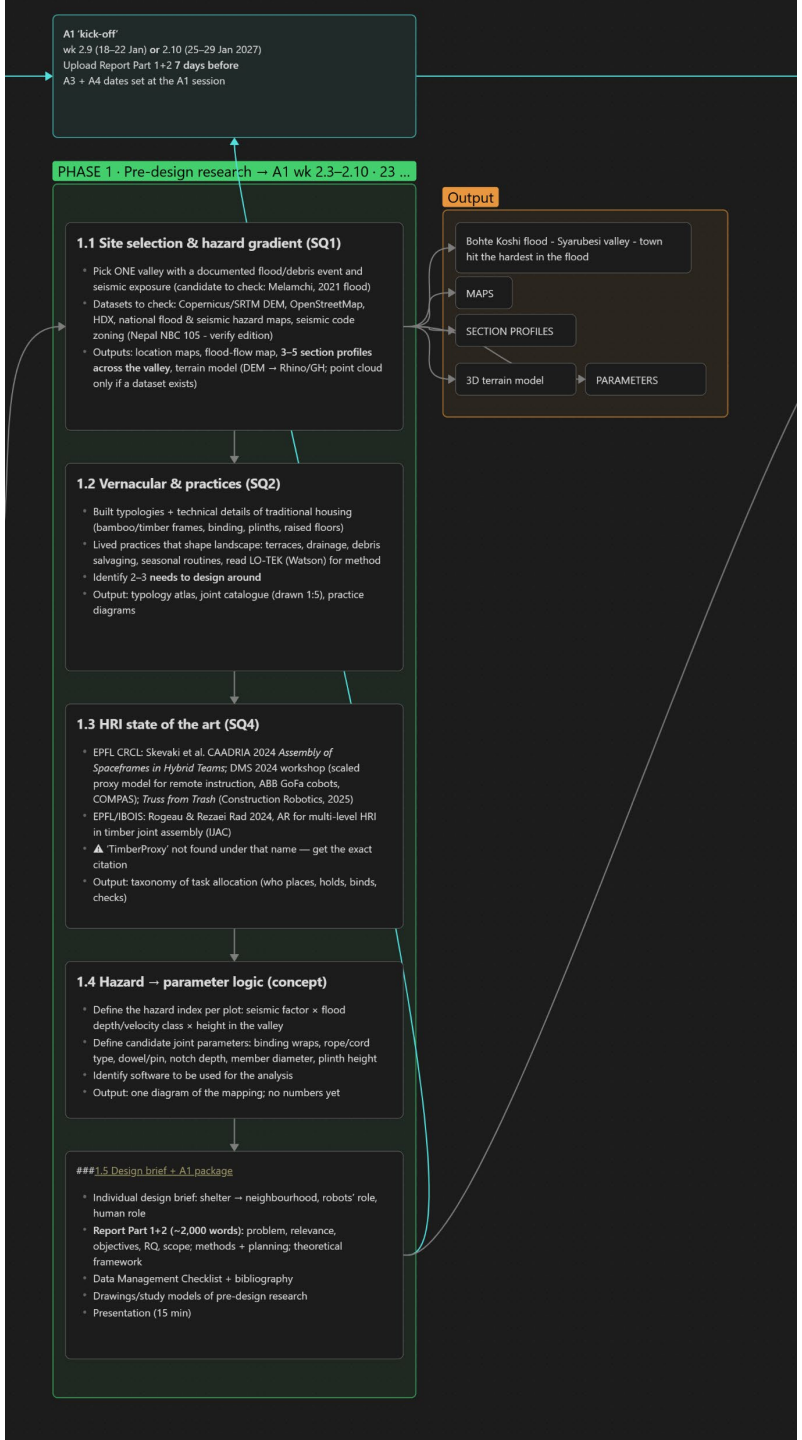
A1 – research and design draft
A2 – parametric definition, robotic HRI workflow and tests, shelter typology + plan
A3 – detailing of assembly system, joint design
A4 – presentation built-up



4. PROJECT PLAN

PHASE 1: Pre-design research – A1

1. Site Selection & hazard gradient
2. Vernacular & practices
3. HRI state of the art
4. Hazard - parameter logic



CHALLENGES

ARGUMENT

how to defend/argue for the implementation of robots with proof + numbers?

RESEARCH APPROACH

to what extent is it relevant to keep the debris reutilization concept/ if so, how detailed?
CV material identification,