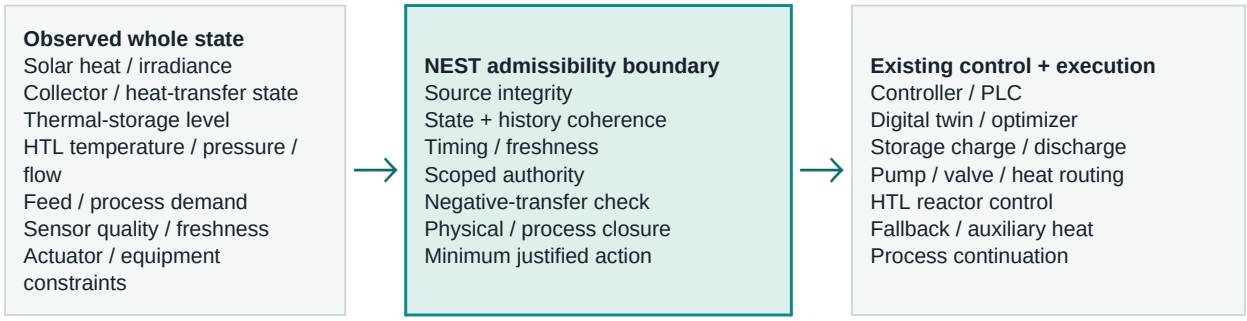
# NEST for Integration & Control of Solar Heat with HTL

A deterministic pre-consequence control and assurance layer for the METU / ODTU-GUNAM solar-assisted hydrothermal liquefaction challenge

**Challenge fit.** ODTU-GUNAM seeks a smart automated system that can dynamically balance fluctuating solar heat supply, thermal storage and HTL reactor operation so the process remains stable and continuous. **NEST fits as the decision boundary around the existing controller, optimizer, digital twin or automation stack.** It evaluates whether a proposed action remains admissible in the complete current state before that action becomes a thermal, process or equipment consequence. The challenge is listed at TRL 4, with pilot-scale integration and control testing as the next step.

## 1. Where NEST sits in the solar-HTL system




| PRESERVE | HOLD | REPAIR | REROUTE | ISOLATE / DENY |
|---|---|---|---|---|
| valid operation proceeds | state not sufficient | recoverable proposal corrected | safe heat / process path | inadmissible consequence contained |

### Why this is a natural NEST test

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| **Coupled-state problem** | Solar collectors, storage and the HTL reactor can each be locally within limits while their combined proposed action is inadmissible for the current process state. |
| **Fast-changing authority** | A valid action can lose authority when solar input, storage availability, reactor state or feed conditions change before execution. |
| **Uncertain / stale evidence** | A sensor can remain syntactically valid while being stale, drifting or inconsistent with the rest of the process. NEST can HOLD or reduce source authority rather than force a decision. |
| **Physical and process closure** | The decision is checked against thermal, pressure, flow, storage, actuator and process constraints before execution rather than only after a fault appears. |
| **Minimum justified intervention** | The objective is stable operation, not maximum blocking: preserve valid control; repair or reroute recoverable actions; isolate or deny only where the bounded consequence is inadmissible. |

## 2. Proposed METU / ODTU-GUNAM validation

**Objective:** determine whether NEST can improve the admissibility and resilience of solar-HTL control under independently defined disturbances while preserving stable, useful reactor operation and avoiding unnecessary intervention.

| Test condition | Challenge to the existing control stack | NEST behaviour / evidence |
|---|---|---|
| Rapid solar drop / ramp | Available heat changes between decision and execution while storage and reactor demand remain coupled. | Re-evaluate present-state admissibility; preserve, hold, repair or reroute before execution. |
| Storage near operating limit | Locally reasonable heat routing would overcharge, under-supply or destabilise the coupled process. | Whole-state closure across solar supply, storage and reactor demand. |
| Stale / conflicting sensor state | Temperature, pressure, flow or storage signals remain valid-looking but become inconsistent or out-of-date. | Bound source authority by freshness/coherence; HOLD or isolate uncertain evidence. |
| Reactor operating-window pressure | A proposed action is valid for the heat subsystem but would move the HTL process outside agreed thermal / pressure / flow constraints. | Physical/process veto before consequence; alternative route if one is admissible. |
| Conflicting objectives | Solar utilisation, storage protection, reactor continuity and equipment constraints pull in different directions. | Minimum justified action; avoid a local optimisation that worsens the complete system state. |

### Validation sequence

• **1. Freeze:** METU / ODTU-GUNAM defines the interfaces, baseline control behaviour, process limits, disturbance families and success metrics before testing.

• **2. Shadow:** NEST receives the same proposed actions and state without altering the reactor or control system.

• **3. Independent challenge:** the challenge owner supplies unseen combinations of solar fluctuation, storage state, sensor quality and HTL operating conditions; all wins, ties, misses, false interventions and indeterminate cases are retained.

• **4. Compare:** baseline vs NEST on valid-operation preservation, out-of-bound consequence prevention, HOLD correctness, repair/reroute success, latency, repeatability and process continuity metrics selected by GUNAM.

• **5. Bounded pilot:** only after agreed shadow criteria are met, activate one narrow reversible control lane in the pilot-scale environment.

### Minimal integration - the NEST invariant stays unchanged

**NEST does not need to become the HTL controller or the solar predictor.** The application-specific work is a thin adapter that maps approved signals and proposed actions into a bounded state: solar heat availability, thermal-storage state, reactor temperature/pressure/flow, feed/process demand, source freshness, actuator constraints and approved physical limits. The existing controller, digital twin or optimiser continues to propose actions; NEST determines whether the resulting consequence is admissible now.

### Existing maturity and claim boundary

| | |
|---|---|
| **Implemented core + evidence** | Deterministic pre-consequence admissibility/control with state/history handling, bounded actions, receipts and replay. Public Proof Pack: boundedsystem.com/demo/proof-pack. Controlled technical artefacts can be supplied for review. |
| **Research basis** | Proposed Pre-Reactive Constraint Law: authority over shared system state must be bounded in the present moment. Publication: zenodo.org/records/18284804 |
| **Claim boundary + collaboration** | NEST has not yet been independently validated on a solar-assisted HTL plant. GUNAM would define and evaluate the pilot conditions; Bounded System Technology would supply the NEST core and solar-HTL adapter. Positive, negative and null outcomes remain part of the evidence. |