OptiCeil: Recoverability-Guided Measurement and Imaging Design

Task-conditioned diagnosis of observer versus measurement limitation

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Abstract

OptiCeil is the measurement-facing recoverability layer of CMH Scientific. It distinguishes observer-limited performance from measurement-limited information under a declared task and representation. The revised v0.2 public release exposes a generic callable client for arbitrary user data and a separate frozen validation layer; production recoverability estimation, geometry search, acquisition ranking, stopping policy, and sensor-selection logic remain protected. Calcium-imaging validation used 914 recording segments, 312 neurons, and 146,962 balanced spike/silent samples with neuron-disjoint transfer: all nine discovery-selected 90/95/99% prescriptions passed the frozen tolerance rule and eight of nine strictly met both nominal quantities. External wearable validation used 82,966 balanced ECG-QRS event/non-event samples from 3,840 recordings and 38 subjects; on identical ACC-capable records, adding accelerometry raised held-out balanced accuracy from 0.5007 to 0.5957 and comparative recoverability from 0.5520 to 0.6148.

Public-release note. This revision aligns the technical report with the September 2026 two-layer software release: a generic callable public interface for new analyses and a separate frozen validation layer for previously reported evidence. Protected operational implementations are not distributed.

1 Purpose

A disappointing model score can arise for two different reasons: useful task information may remain in the measurement but the observer fails to extract it, or the measurement itself may be restrictive for the declared target. The remedies differ. OptiCeil estimates comparative recoverability over declared measurements/representations and separates that quantity from demonstrated held-out performance. When the assumptions do not justify an absolute physical bound, the correct state is `CEILING_UNRESOLVED`.

For acquisition configuration a, let $A(a)$ denote demonstrated held-out performance and $R(a)$ a comparative task-conditioned recoverability quantity over the declared representations or geometries. The tested-representation headroom $G(a) = R(a) - A(a)$ is diagnostic, not a universal law of the instrument.

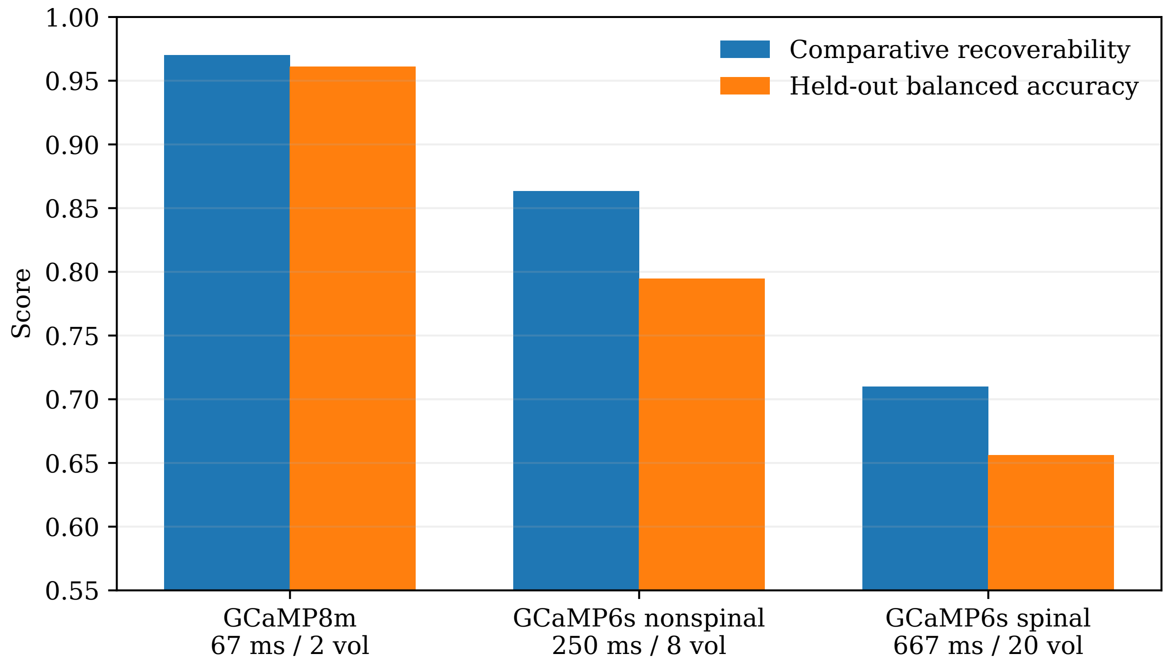

Figure 1: Frozen 99% calcium examples: comparative recoverability and held-out balanced accuracy for the selected tested temporal configurations.

2 Two-layer public release

The public `OptiCeilClient` accepts user data, a declared task, acquisition metadata, and options. It does not embed frozen paper values or perform the protected estimator locally. The separate validation JSON preserves released calcium and external wearable examples.

3 Step-by-step use

1. **Declare the task.** Specify the outcome, validation unit, measurement representation, and scientific question.
2. **Declare the acquisition.** Provide the current temporal window, frames/volumes, sensor, modality, or other measured degrees of freedom.
3. **Call OptiCeil.** Request recoverability and uncertainty/evidence fields for the declared configuration through an authorized transport.
4. **Compare observer and measurement headroom.** High headroom motivates observer/representation work; low headroom with unresolved scientific need motivates tested acquisition redesign.
5. **Delegate constrained selection to Acquire.** OptiCeil diagnoses candidate configurations; Acquire chooses among tested/admissible candidates under burden constraints.

Python public call

```python
from opticeil import OptiCeilClient

client = OptiCeilClient(transport=my_authorized_transport)

result = client.analyze(
    data=my_imaging_or_sensor_data,
    task={"id": "spike_recovery",
          "validation_unit": "neuron"},
    acquisition={
        "sensor": "GCaMP6s",
        "window_ms": 250,
        "volumes": 8,
    },
    options={"return_uncertainty": True},
)

print(result.status)
print(result.recoverability)
print(result.evidence)
```

Example prompt

For this imaging task, determine whether the current limitation is observer-facing or measurement-facing. Compare only tested configurations, show the minimum-burden tested configuration meeting the declared criteria, and state explicitly when an absolute ceiling is unresolved.

Structured result

RESULT: The tested observer can be close to the current representation's recoverability frontier even when the scientific target remains unresolved.
SUPPORTED: comparative protocol selection among tested/admissible configurations and observer-versus-measurement diagnosis conditioned on the declared task.
NOT SUPPORTED: universal physical information ceilings or global optimality across untested acquisition settings.
NEXT ACTION: pass tested candidate configurations to Acquire when measurement redesign is warranted.

4 Validation

4.1 Calcium imaging

The direct imaging validation used 914 recording segments, 312 neurons, 146,962 balanced spike/silent samples, three optical regimes, and 14 temporal windows with neuron-disjoint discovery and held-out validation. All nine discovery-selected 90/95/99% prescriptions passed the frozen tolerance rule; eight of nine strictly met both nominal held-out quantities. The public v0.2 fixture includes the nonspinal GCaMP6s 250 ms / 8-volume example with comparative recoverability 0.863243 and held-out balanced accuracy 0.794551.

4.2 External PPG sensor augmentation

The external BUT Smartphone PPG validation used 82,966 balanced ECG-QRS event/non-event samples from 3,840 recordings and 38 subjects. Expert-good recordings supported higher recoverability than expert-poor recordings in all eight perturbation conditions. On identical ACC-capable records, accelerometry increased held-out BA from 0.5007 to 0.5957 and comparative recoverability from 0.5520 to 0.6148.

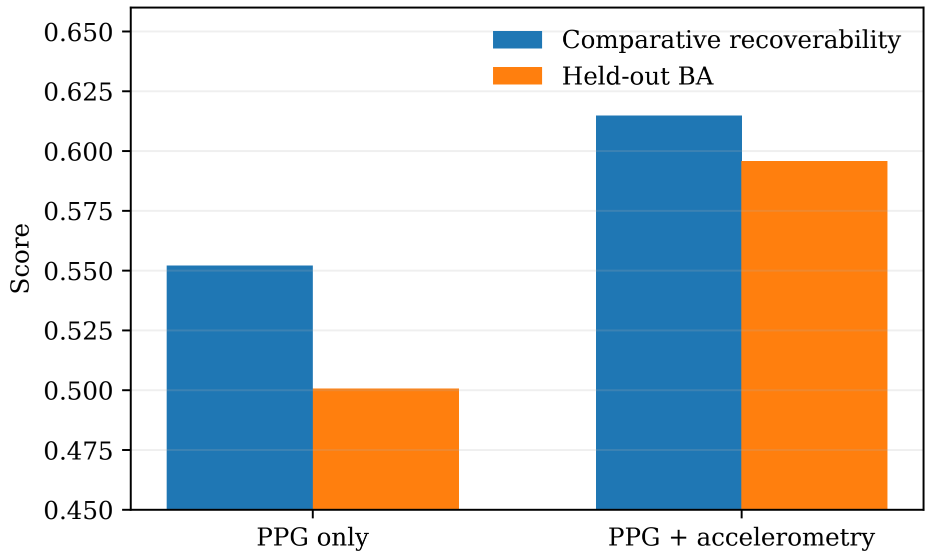

Figure 2: External sensor-value validation on identical ACC-capable records.

5 Boundaries and reproducibility

Recoverability is conditioned on the tested measurement, representation, geometry, task, preprocessing, and validation unit. `CEILING_UNRESOLVED` is a legitimate scientific result. Prospective instrument reconfiguration remains a separate validation requirement.

Public repository: `github.com/ConquerMedical/OptiCeil`. The v0.2 repository exposes a generic client, result schema, frozen validation examples, tests, and a passive demonstrator; protected estimation and acquisition-control algorithms are not distributed.

6 Installation, verification, and result contract

Python public call

```
git clone https://github.com/ConquerMedical/OptiCeil.git
cd OptiCeil
python -m venv .venv
source .venv/bin/activate
pip install -e ".[test]"
pytest -q
python examples/generic_call.py
python examples/frozen_validation.py
```

The public package verifies that arbitrary user data can be submitted through the callable client while frozen examples remain physically separate from the generic path.

Result field	Meaning
`task\_id`	Declared prediction/recovery task.
`status`	Task-conditioned result state.
`recoverability`	Comparative recoverability returned for the declared tested domain.
`uncertainty`	Optional uncertainty quantity returned by the protected engine.
`evidence`	Held-out or validation evidence; each item can include metric, split, and note.
`tested\_domain`	Sensor, anatomy, temporal window, representation, or other tested acquisition metadata.

Table 1: Public OptiCeil result contract.

6.1 Frozen 99% temporal prescriptions

Regime	Window	Volumes	Residual non-ID
GCaMP8m	67 ms	2	0.106
GCaMP6s nonspinal	250 ms	8	0.339
GCaMP6s spinal	667 ms	20	0.688

Table 2: Frozen 99% selected temporal protocols from the public Acquire/OptiCeil validation ledger.

Intellectual property, competing interests, funding, and use

Relevant methods and computational systems are the subject of previously filed U.S. provisional patent applications. This report discloses scientific objects, public interfaces, empirical validation logic, and results needed to evaluate and use the public research architecture. Proprietary operational implementations, calibration internals, candidate-generation procedures, search/ranking policies, deployment orchestration, and other system components not necessary to evaluate the public scientific claims remain outside the scope of disclosure. Publication does not grant a patent or commercial software license.

The author is Founder of Conquer Medical Health and has financial and intellectual-property interests in the technologies described. No external funding supported preparation of this technical report.

Use of AI-assisted tools

AI-assisted tools were used for editorial and software-documentation support. The author determined the scientific claims, supplied the underlying analyses and validation artifacts, and reviewed the numerical content and final report.

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