

GEMSTONE

GEMSTONE: Development and Application of Standards for Automation of Science

Mark Musen

PCL Node Director, Stanford University

PCLNet Kickoff Meeting

September 24–25, 2026, Washington, DC

GEMSTONE Project Team

SITE PRINCIPAL INVESTIGATORS



Mark Musen
Principal Investigator
Stanford University



D.J. Kleinbaum
Co-PI & Science Lead
Emerald Cloud Lab



Gaurav Chopra
Co-PI & AI Lead
Purdue University



Juana Mendenhall
Co-PI & Education Lead
Morehouse College

PROJECT LEADERSHIP



Marcos Martínez-Romero
Project Manager
Stanford University



Kyle Larsen
Science Driver Lead
U.S. Pharmacopeia



Christian Kindermann
Data & Standards Lead
Stanford University



Chester Shiu
Research Security & Biosafety Officer
Emerald Cloud Lab



Ryan Quinn
Operations & User Support Lead
Emerald Cloud Lab

Stanford University
Stanford, CA

Emerald Cloud Lab
Austin, TX

Purdue University
West Lafayette, IN

Morehouse College
Atlanta, GA

U.S. Pharmacopeia
Rockville, MD

Emerald Cloud Lab: 776 instruments online and ready to go





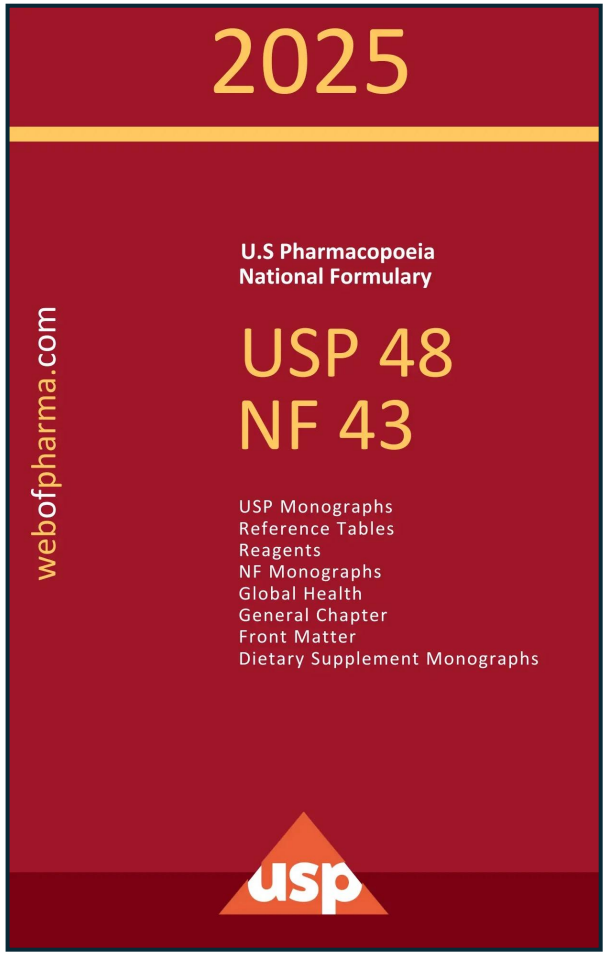


Our initial science driver

Take as input: Text from USP monographs describing procedures for analytical chemistry

Generate as output: Specifications for executing those procedures at Emerald Cloud Lab

Along the way: Translate the text of the USP monograph into an overarching language that can be converted to the specification languages of other cloud labs in the PCL network



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Generalizable Experimental Methods and Standards for Transparent, Open, Networked Execution

Science Drivers

Selected United States Pharmacopeia (USP) analytical procedures

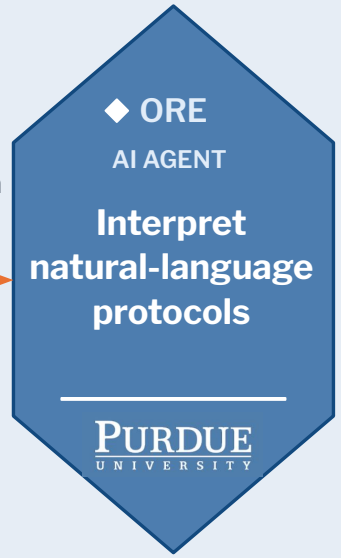
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Science Drivers

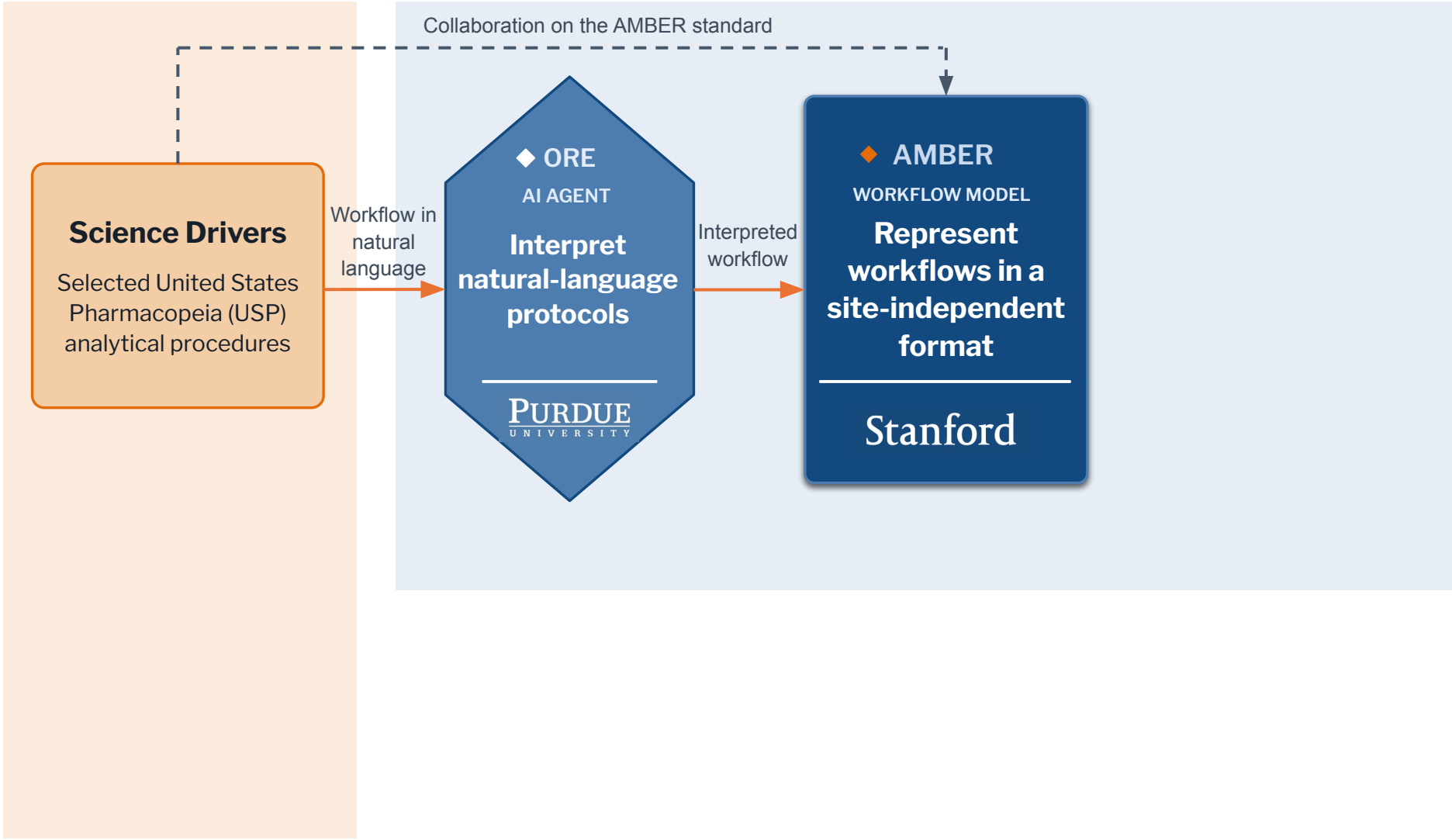
Selected United States Pharmacopeia (USP) analytical procedures

Workflow in natural language



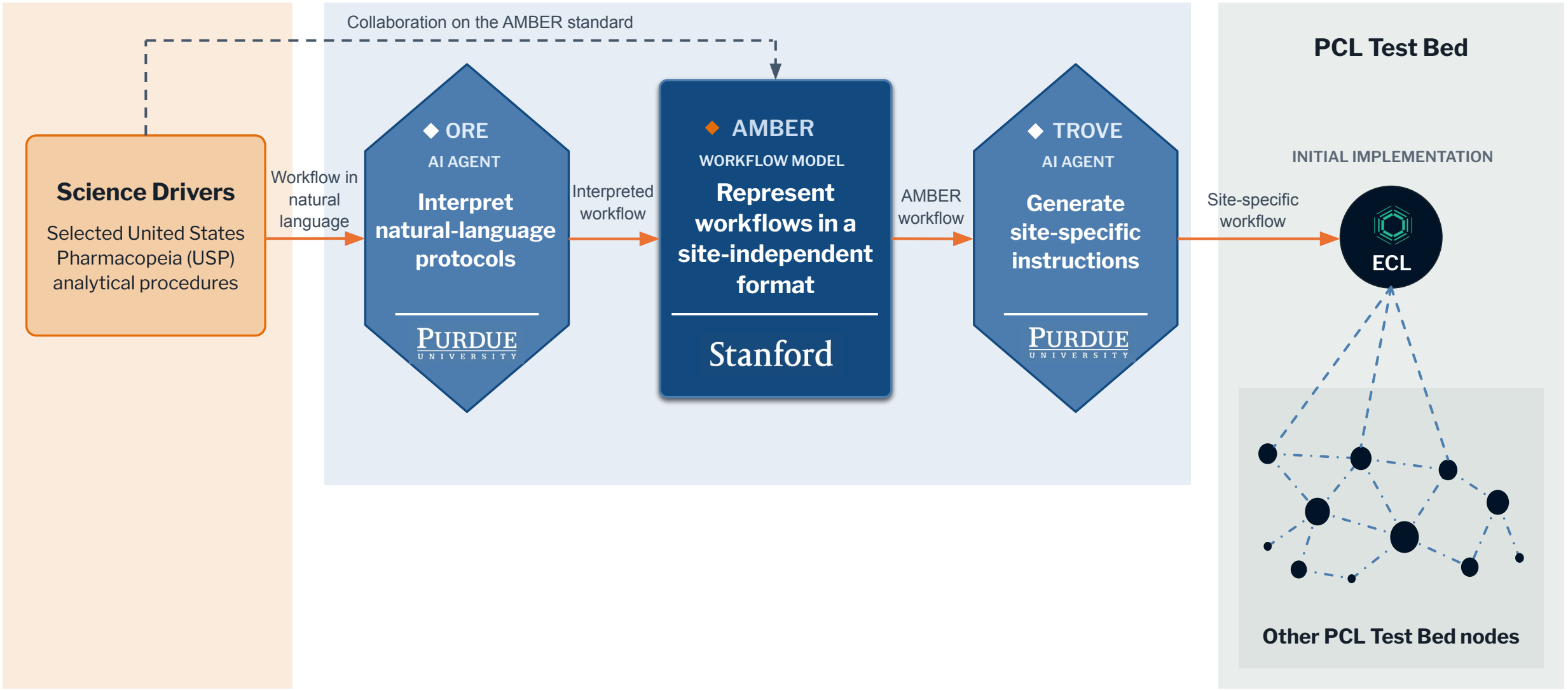
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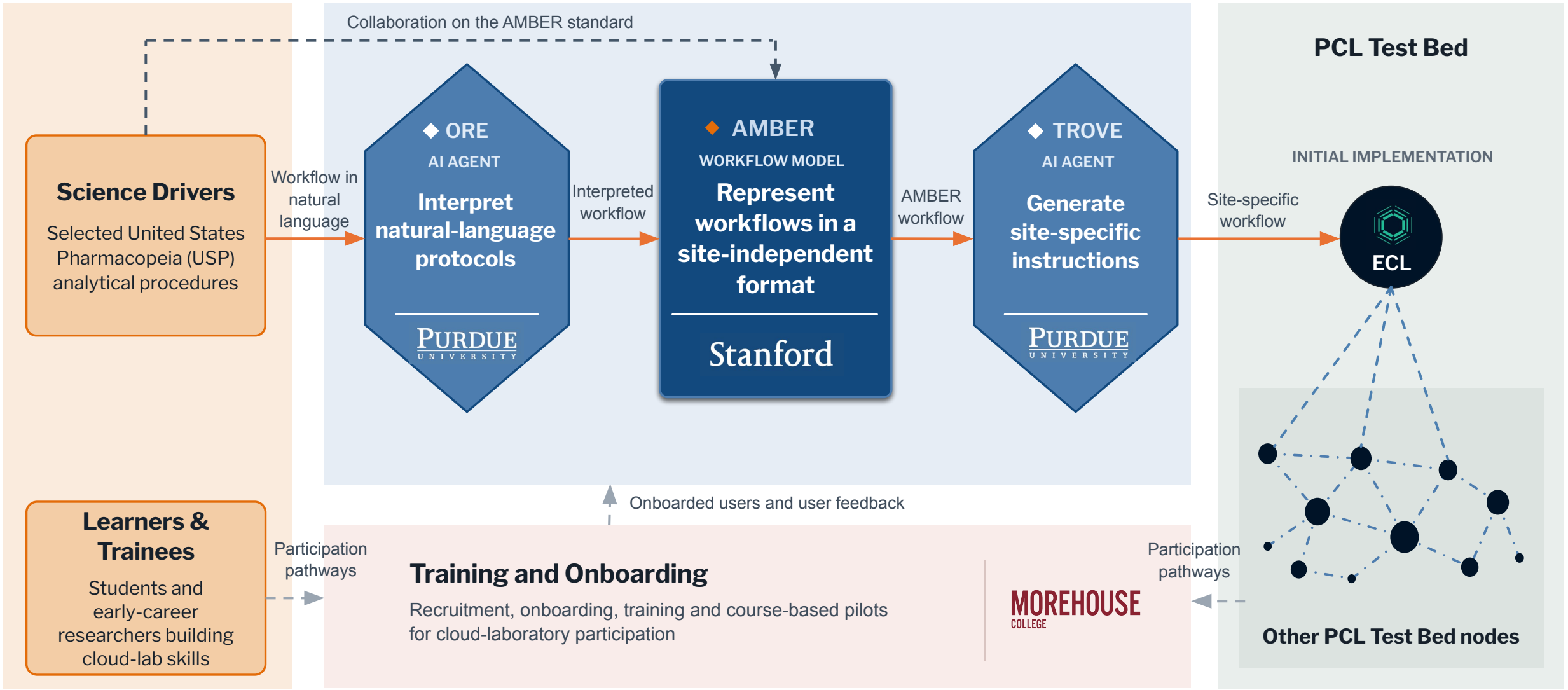
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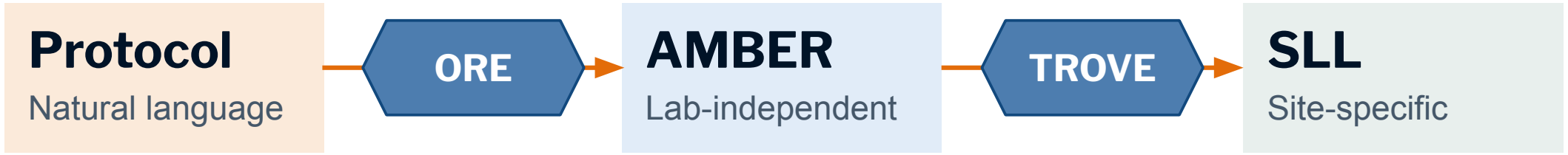


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From a written protocol to cloud-lab instructions



To prepare Solution A, dissolve 1.7 g of monobasic potassium phosphate and 1.8 g of anhydrous dibasic sodium phosphate in 1 L of HPLC-grade water and stir until everything has dissolved.

Container unspecified in source

```
inputs:
  - substance: water
    role: solvent
    grade: HPLC
    amount: {value: 1,
             unit: L}
container:
  type: vessel
mixing:
  method: stir
  until: all_dissolved
```

No specific vessel

```
LabelContainer[
  Label ->
  "Solution A vessel",
  Container -> Model[
    Container, Vessel,
    "2L Glass Bottle"
  ]
]
```

An ECL vessel meeting all requirements

ORE clarifies missing context. TROVE matches requirements to ECL resources

ORE and TROVE: AI agents for protocol translation

Complementary capabilities under development at Purdue University

ORE

- **Convert written protocols** into structured, lab-independent AMBER
- **Resolve ambiguity** with expert input and approved experiments

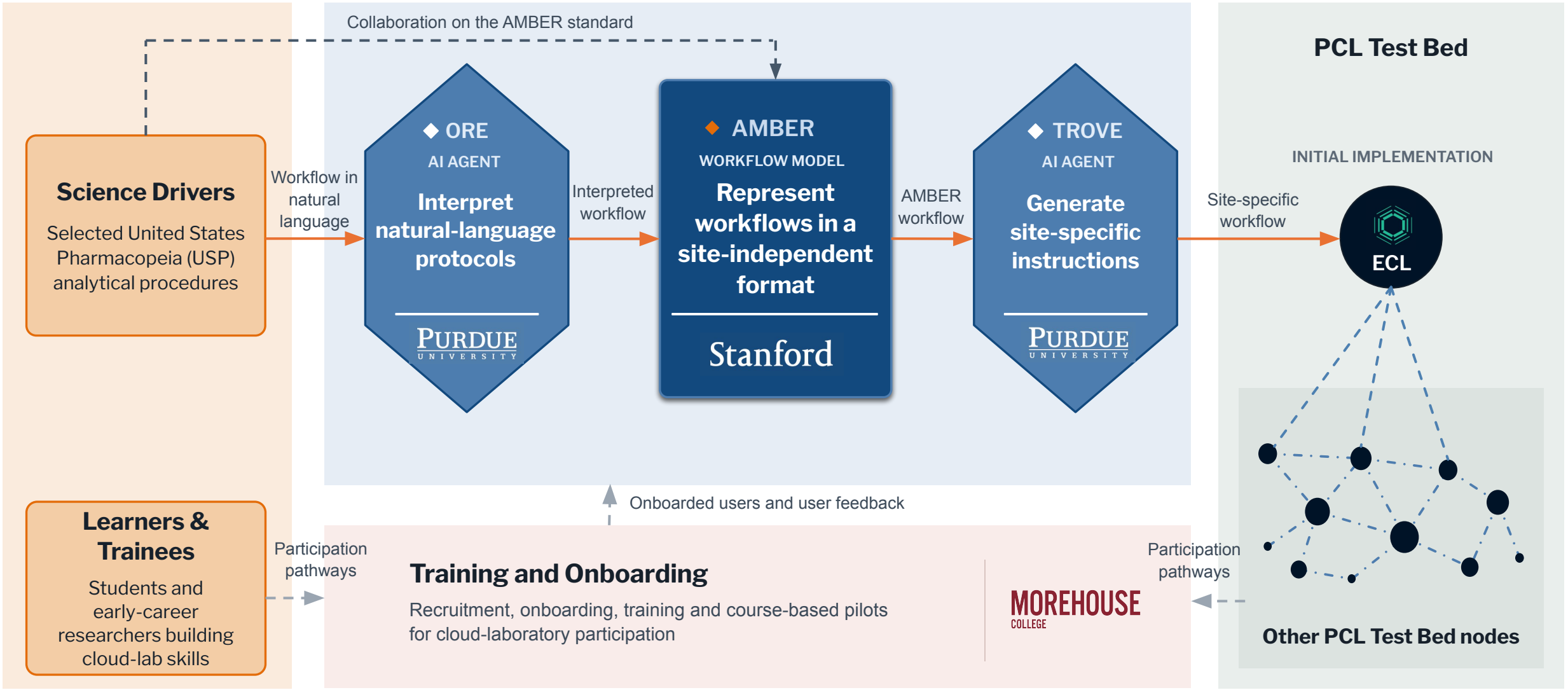
TROVE

- **Translate AMBER** into lab-specific code, starting with ECL's SLL
- **Bind operations** to instruments, materials and containers

Both agents use expert review and experimental feedback to improve their outputs

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Generalizable Experimental Methods and Standards for Transparent, Open, Networked Execution



Education: bringing cloud labs into the classroom

Morehouse-led faculty training and course pilots, supported by GEMSTONE partners

Broaden access	Recruit faculty nationally, emphasizing outreach to under-resourced institutions.
Build skills	Offer remote onboarding and guided practice using existing ECL training resources.
Pilot courses	Help faculty integrate cloud-lab modules into existing undergraduate courses.
Learn and share	Use feedback to improve training and share reusable teaching materials.

Goal: broaden participation and build practical cloud-laboratory skills

GEMSTONE: Opportunities to collaborate

- **For other PCL nodes,** contribute to an infrastructure that ultimately
  - Will allow experiment-design systems to output specifications for execution at a variety of nodes
  - Will allow interconversion of experiment specifications across nodes
- **For industry,** help us to extend, harden, and validate this infrastructure
- **For federal agencies,** help us to begin the process of creating standards for interoperability among programmable cloud labs, much as the government jump-started the process for CAD/CAM in the 1980s



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