Case Study

Zymergen

Optimized Factory Scheduling for **Synthetic Biology**

Abseil Automation
abseil.ai

Executive Summary

Zymergen, a molecular technology company, uses AI and robotics to engineer microbes to manufacture novel molecules and materials. The company integrates automation, machine learning, and genomics in ways that push the limits of conventional scheduling solutions.

Zymergen's primary production challenge is logistical. Zymergen has pioneered Reconfigurable Automation Carts (RACs), modular laboratory hardware containers and connectors that allow for virtually unlimited arrangements. RACs augment Zymergen's production capabilities significantly, but can't be modeled in off-the-shelf scheduling solutions. That means Zymergen can't get the most out of its investment if it uses OTS schedulers.

Variability in order size and complexity, in particular, is difficult to model. Some of Zymergen's orders require only two scientific instruments; others require dozens. Scheduling and modeling interdepencies between instruments is a significant challenge.

Faced with a scheduling challenge that humans and off-the-shelf software solutions could not model or optimize, Zymergen partnered with Abseil Automation to deploy an advanced scheduling solution that maximized throughput, helped Zymergen baseline and ensure correct manufacturing performance, and drastically reduce capital expenditures.

Key Success Measures

The Abseil Automation solution was able to:

- **Schedule dozens of instruments simultaneously, with room to expand to the full production floor.** This includes instruments and transports not designed to work together.
- **Increase throughput by 1.3-3.4x.** By streamlining production sequences, Abseil enabled hardware configurations that produced significant gains in throughput over baseline.
- **Reduce capital expenditure by up to two thirds.** Abseil's solution helped ensure that Zymergen didn't purchase unnecessary equipment.

Problem

Zymergen runs thousands of chemical and biological experiments daily to test novel molecules in high throughput, largely because it is able to integrate automation, machine learning, and genomics capabilities that competitors cannot. That complexity poses a scheduling challenge.

The breadth of orders that Zymergen handles means that its laboratory needs to be modular and reconfigurable by design. Some orders require only two instruments; others require dozens. That variability poses a significant challenge for conventional scheduling systems.

Zymergen decided to combine expensive laboratory equipment such as thermocyclers and liquid handers from different manufacturers into modular configurations called Reconfigurable Automation Carts (RACs) into its manufacturing process and recognized that a high performance scheduler is required to unlock the utility of a novel hardware configuration. They approached Abseil to supply this critical component. The combination of an optimal scheduler with Zymergen's hardware configuration solved four major operational problems: suboptimal throughput, stranded capital expenditures, lack of extensibility, and lack of technology flexibility.

Fig. 1. Factory scheduling and output affect every department at Zymergen.

Zymergen's Existing Scheduling Approach Was Difficult to Scale

Suboptimal throughput, with limited ability to baseline or benchmark production

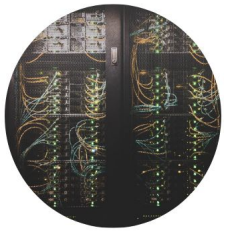
Prior to engaging with Abseil, Zymergen's scheduling process couldn't account for, among other things, concurrent production protocols on shared hardware or bespoke combinations of hardware from different manufacturers. Zymergen tracked key cluster utilization metrics and performed some simulation-based modeling, but it didn't know how far it was from maximum throughput.

Millions of dollars in stranded capital expenditures

Zymergen spent millions building and designing production systems for one specific problem or order type, but needed a solution to help incorporate the hardware or production modules within those systems for new orders. Its existing scheduling solution was only able to partially model the lab environment, particularly heterogeneous robotic transport mechanisms.

An inability to reconfigure or extend existing systems in a logical, cost-effective way

OTS scheduling systems couldn't tell Zymergen where existing bottlenecks were, or, given the complex dependencies throughout the production line, whether new investments would lead to a meaningful increase in throughput. As a result, Zymergen had difficulty optimizing for cost when investing in new equipment.



No cloud-ready, scalable scheduling interface

Prior to the deployment of the Abseil solution, there was a limitation on the maximum complexity and length of an auto-schedulable lab protocol. Together with Zymergen, Abseil developed a cloud-ready interface.

The Abseil Solution

Abseil first partnered with Zymergen to analyze manufacturing capabilities and dependencies across different types of laboratory equipment (e.g., liquid handlers, robotic loading arms, and longer-distance transport mechanisms), such as state interactions and special constraints.

Then, Abseil developed an extensible system model, input format for programmatic specification of device clusters and protocol contents, and a unifying software suite to tie it all together and pass it to the Abseil Scheduling Engine.

Finally, Abseil deployed the solution and tested it on a range of Zymergen's hardware configurations and production protocols, additionally refining the product with feature requests reflecting on-the-ground production conditions and needs.

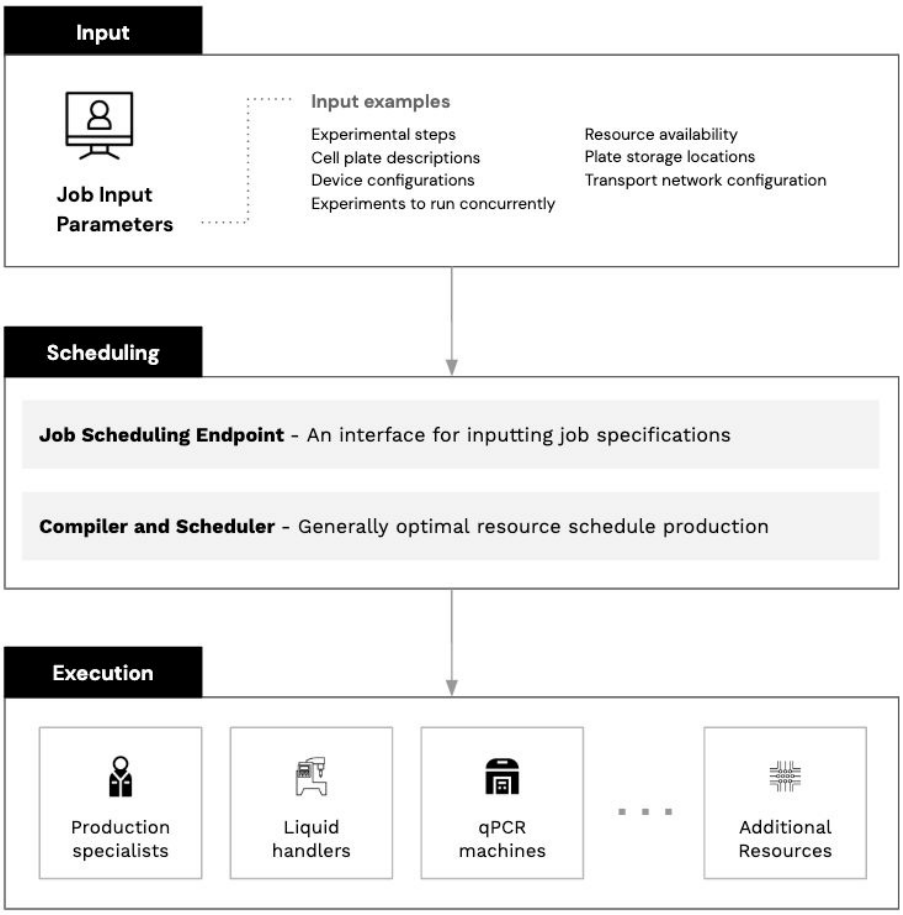
Project Plan for Abseil's Engagement with Zymergen			
	Phase 1 Analysis of factory capabilities and dependencies	Duration 1 month	Key Findings ● No automatic production scheduling ● No support for concurrent operations ● Long planning cycles
	Phase 2 Deployment of a proven scheduling engine	Duration 6 months	Key Results ● Programmatically accessible scheduling ● Generally optimal and truly concurrent scheduling ● Cloud-deployable scheduling solution ● Execution-safe and state-aware software ● Avoidance of unnecessary auxiliary hardware
	Phase 3 System rollout, user training, and iteration	Duration 3 months	Key Deliverables ● Thorough system documentation and training ● Gradual hand-off process and meetings ● On-call support for bug fixes

Solution Diagram

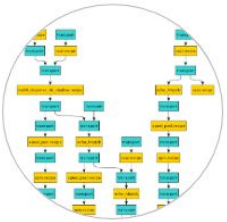
There are three components of the scheduling solution:

1. **Input.** The input of the solution requires the collection of job input parameters, such as device cluster configuration.
2. **Scheduling.** The scheduling component of the solution includes a programmatic interface, and an operating system that transforms and schedules the job inputs using Abseil's specialized algorithms.
3. **Execution.** The execution component of the solution includes instructions with timings for all production resources.

Fig. 2. From input to execution, Abseil offers an end-to-end solution for scheduling.

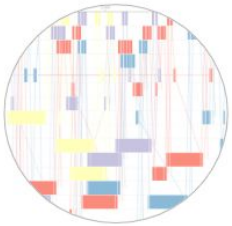


Abseil's Solution Ensures Process Reproducibility and Cost-Effectiveness



Formalization of production processes

By eliminating human guesswork and formalizing written protocols, high reproducibility is achievable. Abseil's solution ensured the ability to revision and store protocol execution schedules. This complemented Zymergen's human-readable input revisioning, which Abseil's solution compiled into valid device instruction sequences.



Generation of production schedules within minutes

This capability enables Zymergen to adapt in near real time in response to new demand or unexpected factory floor interruptions such as machine downtime.

Novel configurations and devices are supported, regardless of how new investments interact with existing scientific instruments

Because new device definition is so simple, novel device types can be directly modeled into the extensible system.

Full leverage of production facility real estate

Rather than being constrained to one robotic arm surrounded by a circle of devices (as the previous solution required), Zymergen is now able to leverage their unique hardware and software capabilities to arbitrarily design their factory layout to fill their available real estate.

Appendix:
Implementation

Phase 1. Analysis of factory capabilities and dependencies

Abseil's partnership with Zymergen began with an in-depth analysis of the company's unique production challenges. This analysis included interviews with stakeholders, a hardware survey, identification of the most critical business needs, and finally technical scoping of proposed solutions. Challenges identified during analysis included:

Limited automatic production scheduling. Dynamic, modular clusters of instruments could not move beyond the prototype stage with production planning involved humans in the loop. Downsides of this include difficulty of scaling, and extra variables that can affect experimental reproducibility. Non-programmatic scheduling also meant that protocols could not be efficiently re-scheduled in the case of operational delays or individual device malfunction during execution.

No support for concurrent operations. Zymergen lacked the ability to concurrently transport multiple payloads (such as plates of cells), both because of an inability to model fundamental (and complex) factory elements such as transportation, as well as because of the algorithmic complexity. The result was significant hardware under-utilization.

Long planning cycle times. Zymergen struggled to forecast future factory expansion because without an optimal Scheduling Engine, purchasing decisions were made blind to essential knowledge regarding cluster throughput capabilities.

Phase 2. An optimized Scheduling Engine

Abseil was able to leverage its Scheduling Engine and experience with automation ("which robot should do what when?") and process scheduling ("how to schedule complex interdependent jobs?") to begin delivering a solution shortly after the analysis/scoping portion of the project was completed. Abseil's solution and Scheduling Engine solved what OTS software couldn't by incorporating the following features:

Programmatically accessible. Abseil's solution requires no human interaction; it can be hooked up as a service directly to a production system.

Generally optimal and truly concurrent. The Abseil Scheduling Engine is based on cutting-edge mathematical optimization research that can, in most cases, prove optimality of the solution. OTS solutions fundamentally could not model multiple payload transports simultaneously, whereas the Abseil solution can schedule a large number. The Abseil solution also differentiates between devices which can execute multiple workflows in parallel (e.g. storage-type devices), versus those that are locked exclusively to one workflow at a time, forming the most complete process model and therefore allowing it to be optimized.

Configuration-flexible and cloud-deployable. Abseil's solution accepts any configuration of devices and transport networks, for any factory setup or scale. The solution endpoint can be deployed both in the cloud (such as Amazon EC2) as well as on-premise, in contrast with OTS software that requires hardware co-located with lab devices, and carries opaque and non-scalable licensing costs. Abseil's solution can be accessed remotely, and removes a major operational friction point for highly scalable, modular, and reconfigurable factories.

Execution-safe and state-aware. Experimental execution can be paused, or aborted and restarted later, because the solution maintains state awareness regarding payload location and device operation.

Avoiding unnecessary auxiliary hardware. Abseil's solution doesn't require any additional hardware such as sensors, or "digital twin" replication of the factory setup, which supports flashy visualization but poorly addresses the core challenges of operational performance.

Phase 3. System rollout, user testing, iteration of feature requests

Abseil rolled out the solution incrementally over the course of months, and responded to feedback and feature requests reflecting unanticipated on-the-ground conditions. Thorough

documentation was developed, and handoff meetings were held with Zymergen's in-house developers to ensure a smooth transition.

Because of handoff to a technical team, certain system modeling was intentionally left open to future extensibility and development. Abseil remained on-call for bug fixes through the end of the handoff period.