

The background is a vibrant, multi-colored gradient. It features a diagonal split between a blue-purple gradient on the left and an orange-yellow gradient on the right. The text 'AWS re:Invent' is rendered in white, with 'AWS' in a smaller font size above 're:Invent'.

AWS  
re:Invent

LFS 202

# Digital therapeutics and patient personalization

**Greg Tracy**

CTO  
Propeller Health

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Senior Solution Architect  
Amazon Web Services

# Agenda

What are digital therapeutics?

Digital therapeutics on AWS: Architecture overview

Propeller Health's digital solution

Propeller Health's architecture

Questions

# What are digital therapeutics?

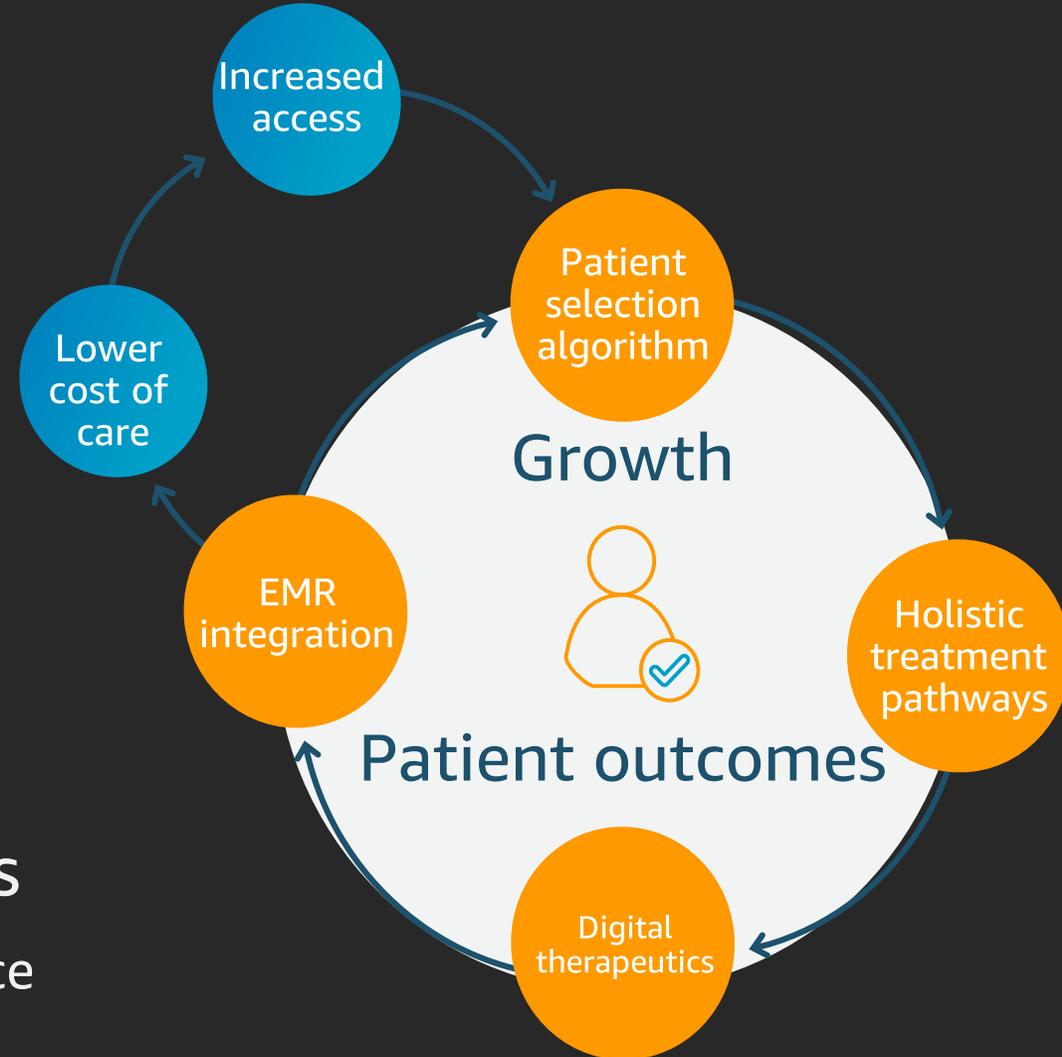
“Digital therapeutics (DTx) deliver evidence-based therapeutic interventions to patients that are driven by high quality software programs to prevent, manage, or treat a broad spectrum of physical, mental, and behavioral conditions.”

**Digital Therapeutics Alliance**

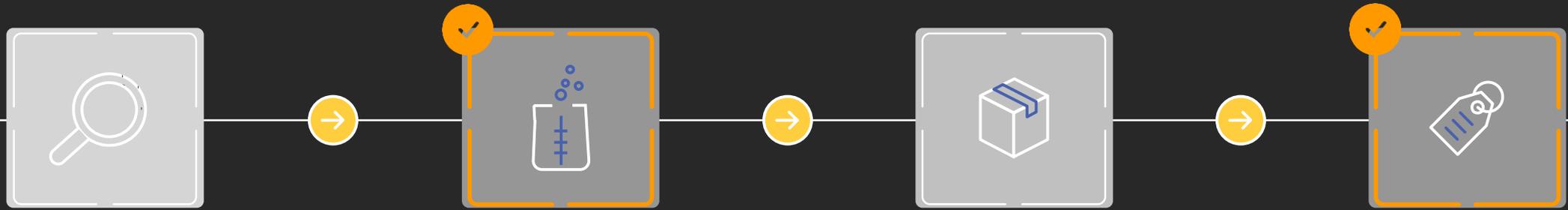
<https://dtxalliance.org/dtx-solutions/>

# Why digital therapeutics?

- Enhance, support, and extend current treatments
  - Extend and differentiate existing therapies, increasing their lifespan and efficacy
- Patient-centered care
  - Meet patients where they are (versus at the clinician's office)
  - Data can be used to enhance adherence and influence patient behavior
- Broad impact across many therapy areas
  - Asthma, hypertension, smoking cessation, substance abuse, insomnia, ADHD, diabetes management, pediatric behavioral health



# Digital therapeutics in the value chain



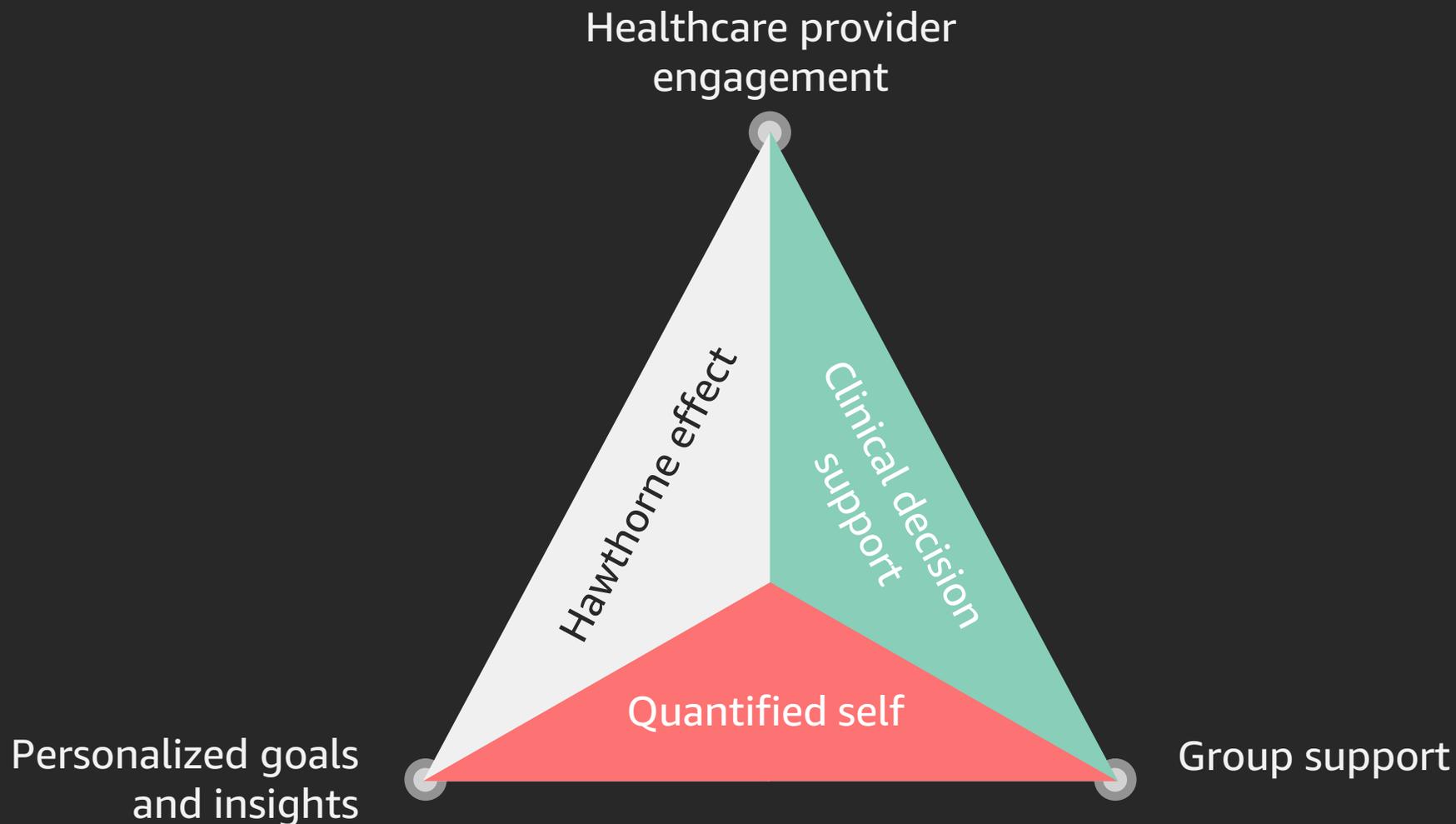
Early-phase research

*Clinical trials*

Manufacturing

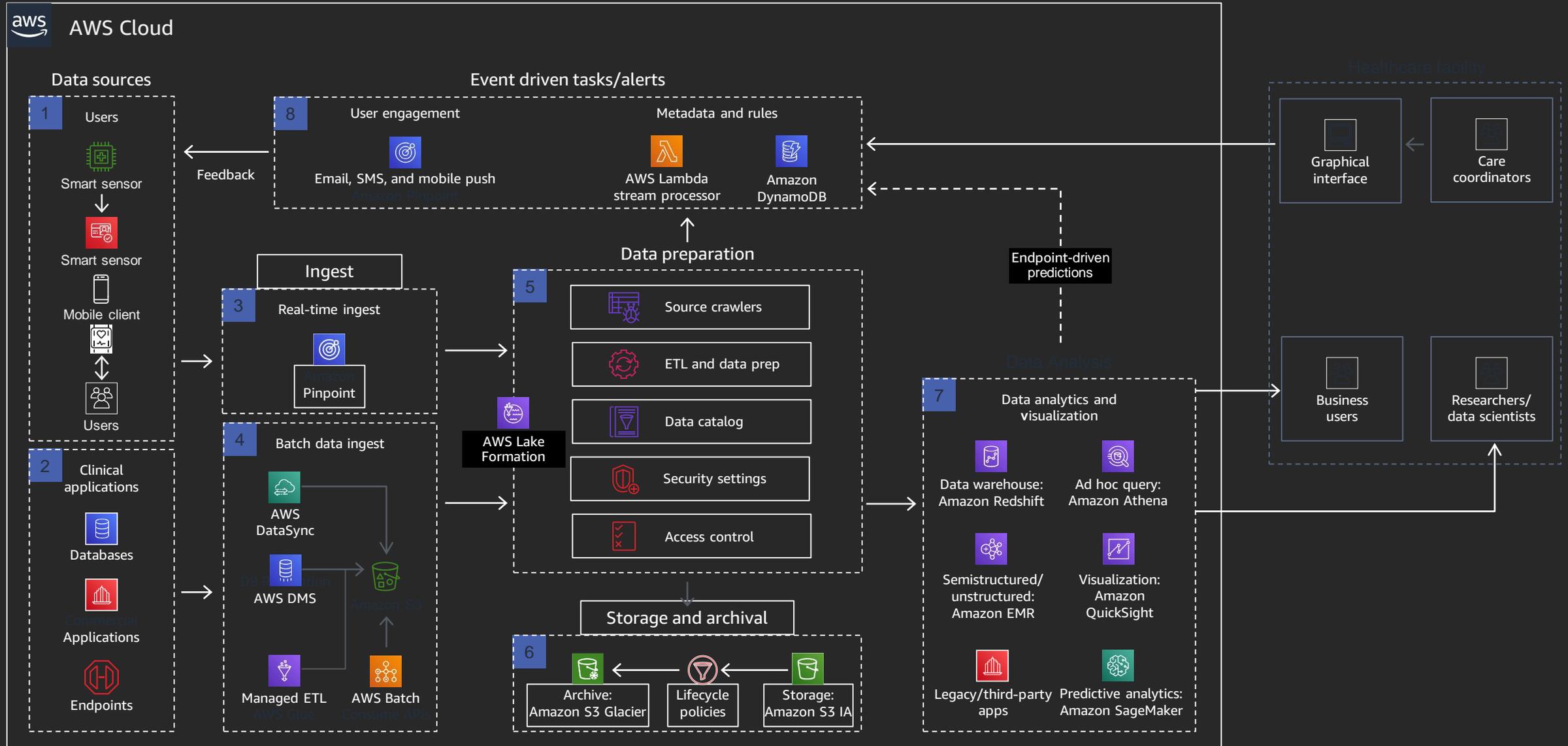
*Commercialization*

# Digital therapeutics “success triangle”



# Digital therapeutics and precision medicine

## AWS reference architecture



# Propeller Health

# Respiratory medications are very effective

## ASTHMA & COPD MEDICATIONS

### SABA RELIEVERS



**Bricanyl Turbuhaler** †<sup>▲</sup>  
terbutaline 500mcg



**Ventolin Inhaler** †<sup>▲</sup>  
salbutamol 100mcg



**AiroMir Autohaler** †<sup>▲</sup>  
salbutamol 100mcg



**Asmol Inhaler** †<sup>▲</sup>  
salbutamol 100mcg

### NON STEROIDAL PREVENTERS



**Singular Tablet** <sup>ⓐ</sup>  
montelukast  
4mg • 5mg • 10mg



**Montelukast Tablet** <sup>ⓐ</sup>  
montelukast  
4mg • 5mg • 10mg  
Generic medicine suppliers



**Intal Inhaler** †  
sodium cromoglycate  
1mg • 5mg<sup>†</sup>  
<sup>†</sup>Intal Forte



**Tilade Inhaler** †  
nedocromil sodium  
2mg

### ICS PREVENTERS



**Flixotide Inhaler** †  
fluticasone propionate  
50mcg<sup>†</sup> • 125mcg • 250mcg  
<sup>†</sup>Flixotide Junier



**Fluticasone Cipla Inhaler** †  
fluticasone propionate  
125mcg • 250mcg



**Flixotide Accuhaler** †  
fluticasone propionate  
100mcg<sup>†</sup> • 250mcg • 500mcg



**Pulmicort Turbuhaler** †  
budesonide  
100mcg • 200mcg • 400mcg



**QVAR Inhaler** †  
beclomethasone  
50mcg • 100mcg



**QVAR Autohaler** †  
beclomethasone  
50mcg • 100mcg

### SAMA MEDICATION



**Atrovent Metered Aerosol** †<sup>▲</sup>  
ipratropium 21mcg



**Alvesco Inhaler** †  
ciclesonide  
80mcg • 160mcg

### ICS/LABA COMBINATIONS



**Symbicort Turbuhaler** ‡  
budesonide/formoterol  
100/6 • 200/6 • 400/12 #



**DuoResp Spiromax** ‡  
budesonide/formoterol  
200/6 • 400/12 #



**Symbicort Rapihaler** ‡  
budesonide/formoterol  
50/3 • 100/3 • 200/6 #



**Flutiform Inhaler** ‡  
fluticasone propionate/formoterol  
50/5 • 125/5 • 250/10



**Seretide MDI** ‡  
fluticasone propionate/salmeterol  
50/25 • 125/25 • 250/25 #



**Fluticasone + Salmeterol Cipla Inhaler** ‡  
fluticasone propionate/salmeterol  
125/25 • 250/25 #



**Seretide Accuhaler** ‡  
fluticasone propionate/salmeterol  
100/50 • 250/50 • 500/50 #



**Breo Ellipta** ‡  
fluticasone furate/vilanterol  
100/25 # • 200/25

### LABA MEDICATIONS



**Oxis Turbuhaler** ‡  
formoterol  
6mcg • 12mcg



**Serevent Accuhaler** ‡  
salmeterol  
50mcg



**Onbrez Breezhaler** <sup>▲</sup>  
indacaterol  
150mcg • 300mcg

### LAMA MEDICATIONS



**Spiriva Respimat** # ‡  
tiotropium 2.5mcg



**Spiriva Handihaler** #  
tiotropium 18mcg



**Bretaris Genuair** #  
acloninium 322mcg



**Seebri Breezhaler** #  
glycopyrronium 50mcg



**Incruse Ellipta** #  
umeclidinium 62.5mcg



**Trelegy Ellipta** <sup>Ⓒ</sup>  
fluticasone furoate/  
umeclidinium/vilanterol  
100/62.5/25

### LAMA/LABA COMBINATIONS



**Spiolto Respimat** <sup>Ⓒ</sup>  
tiotropium/olodaterol  
2.5/2.5



**Brimica Genuair** <sup>Ⓒ</sup>  
acloninium/formoterol  
340/12



**Ultibro Breezhaler** <sup>Ⓒ</sup>  
indacaterol/glycopyrronium  
110/50



**Anoro Ellipta** <sup>Ⓒ</sup>  
umeclidinium/vilanterol  
62.5/25

ICS, inhaled corticosteroid | LABA, long-acting beta<sub>2</sub> agonist | LAMA, long-acting muscarinic antagonist | SABA, short-acting beta<sub>2</sub> agonist | SAMA, short-acting muscarinic antagonist

This chart was developed independently by the National Asthma Council Australia with support from Boehringer-Ingelheim, GSK Australia, Mundipharma and Teva Pharma Australia



2018

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### RESOURCES

#### TREATMENT GUIDELINES

Australian Asthma Handbook: [astmahandbook.org.au](http://astmahandbook.org.au)

COPD-X Plan: [copdx.org.au](http://copdx.org.au)

#### INHALER TECHNIQUE

How-to videos, patient and practitioner information

[nationalasthma.org.au](http://nationalasthma.org.au)

Inhalers/MDIs should be used with a compatible spacer

PBS PRESCRIBERS † Asthma unrestricted benefit ‡ Asthma restricted benefit <sup>ⓐ</sup> Asthma authority required <sup>▲</sup> COPD unrestricted benefit # COPD restricted benefit <sup>Ⓒ</sup> COPD authority required Check TGA and PBS for current age and condition criteria

But our treatment approach has not evolved

Your name:

Today's date:



### How is your COPD? Take the COPD Assessment Test™ (CAT)

This questionnaire will help you and your healthcare professional measure the impact COPD (Chronic Obstructive Pulmonary Disease) is having on your wellbeing and daily life. Your answers, and test score, can be used by you and your healthcare professional to help improve the management of your COPD and get the greatest benefit from treatment.

For each item below, place a mark (X) in the box that best describes you currently. Be sure to only select one response for each question.

**Example:** I am very happy  0  1  2  3  4  5 I am very sad

			SCORE
I never cough	<input type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	I cough all the time	<input type="text"/>
I have no phlegm (mucus) in my chest at all	<input type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	My chest is completely full of phlegm (mucus)	<input type="text"/>
My chest does not feel tight at all	<input type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	My chest feels very tight	<input type="text"/>
When I walk up a hill or one flight of stairs I am not breathless	<input type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	When I walk up a hill or one flight of stairs I am very breathless	<input type="text"/>
I am not limited doing any activities at home	<input type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	I am very limited doing activities at home	<input type="text"/>
I am confident leaving my home despite my lung condition	<input type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	I am not at all confident leaving my home because of my lung condition	<input type="text"/>
I sleep soundly	<input type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	I don't sleep soundly because of my lung condition	<input type="text"/>
I have lots of energy	<input type="radio"/> 0 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	I have no energy at all	<input type="text"/>
			<b>TOTAL SCORE</b> <input type="text"/>



# As a result, we're not making progress.



**\$100 billion**

in annual  
spending for  
asthma & COPD



**1,150,000**

yearly  
hospitalizations  
(many avoidable)



**22%**

COPD 30-day  
readmission  
rate



**65%**

of patients with  
asthma are  
uncontrolled

# People deserve a better approach to respiratory care



More  
accessible



More  
personal



More  
powerful



More  
convenient

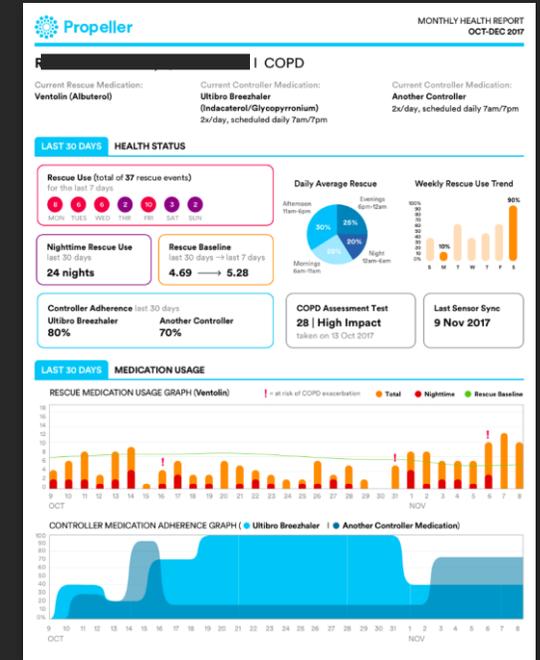
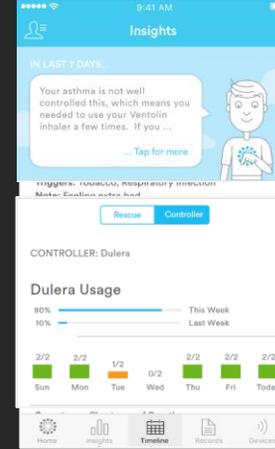
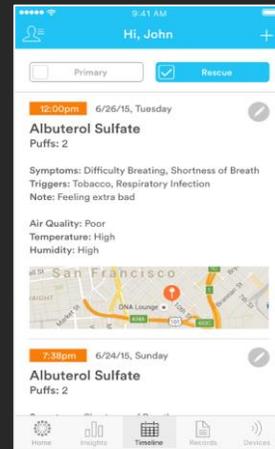


# Propeller is a complete solution for respiratory disease

Patient/caregiver experience

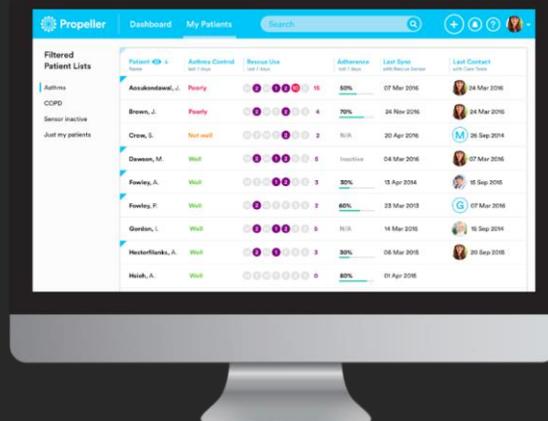
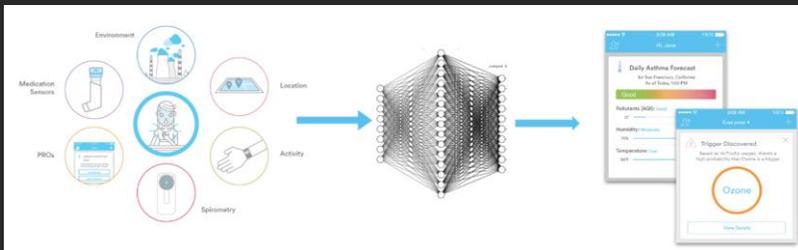
Clinical reports

Connected medicines



Care team dashboards

Data science and analytics



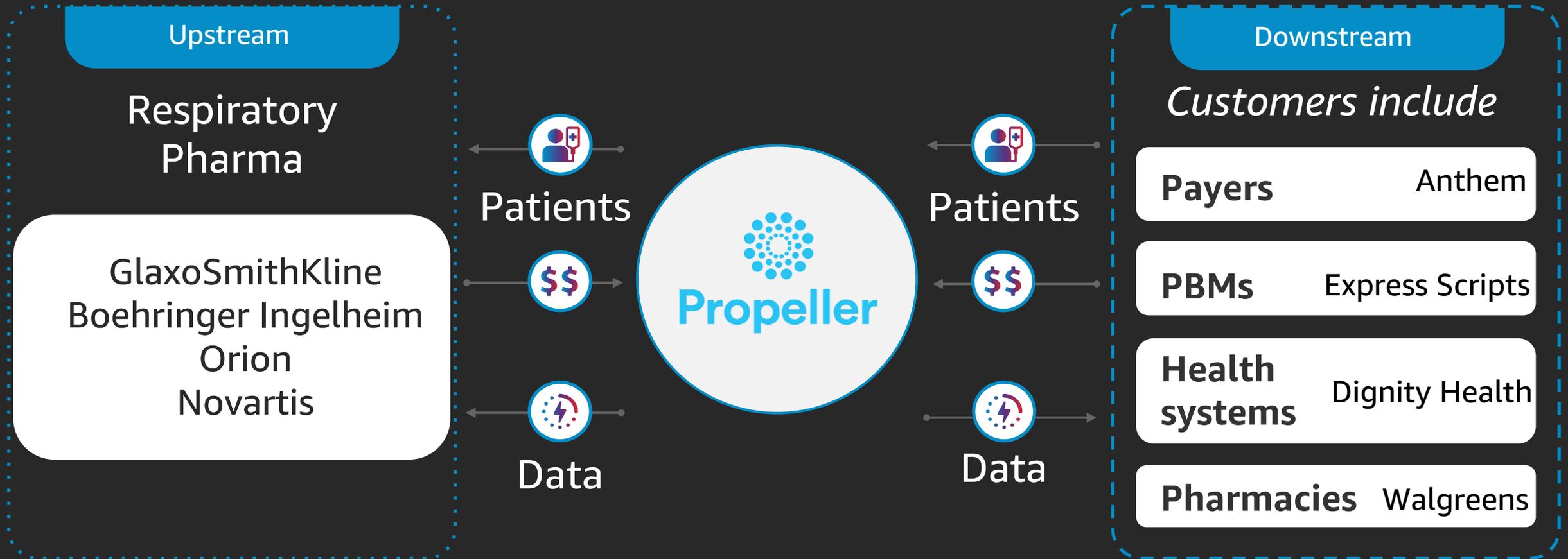
Clinical alerts

 **Jane Doe is at risk of asthma exacerbation today.**

FEB 21



# Our commercial model is built on a 2-sided network



# Clinical outcomes (asthma): Decreased ED + hospital

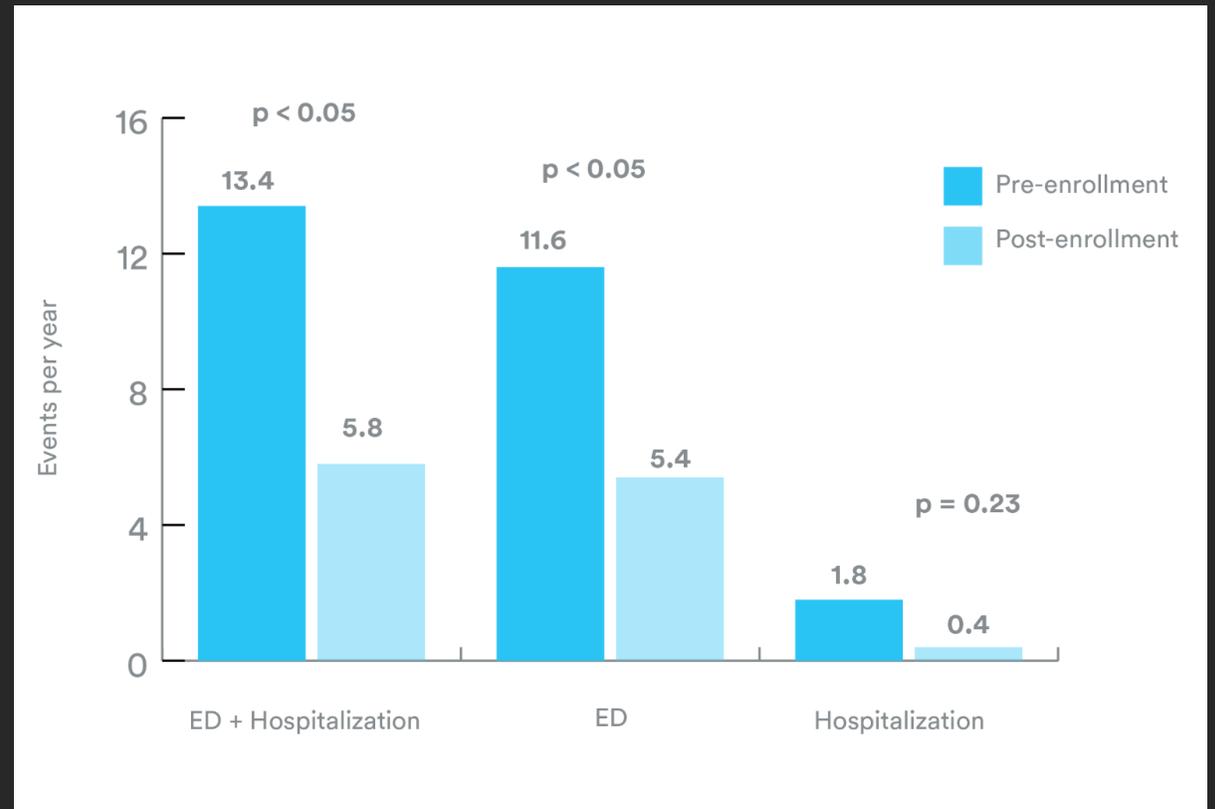
## Study overview

Dignity Health patients were enrolled from 2014 to 2017 during routine asthma care and monitored for at least 1 year. Providers monitored SABA use and adherence to inhaled controller medications, and provided follow-up as needed.

## Population

- Patients with asthma who were prescribed a SABA and who had no comorbidities
- N = 224; mean age: 33 years; 43% male; 53% used ICS only and 17% used ICS/LABA, 30% used another controller medication

## Results



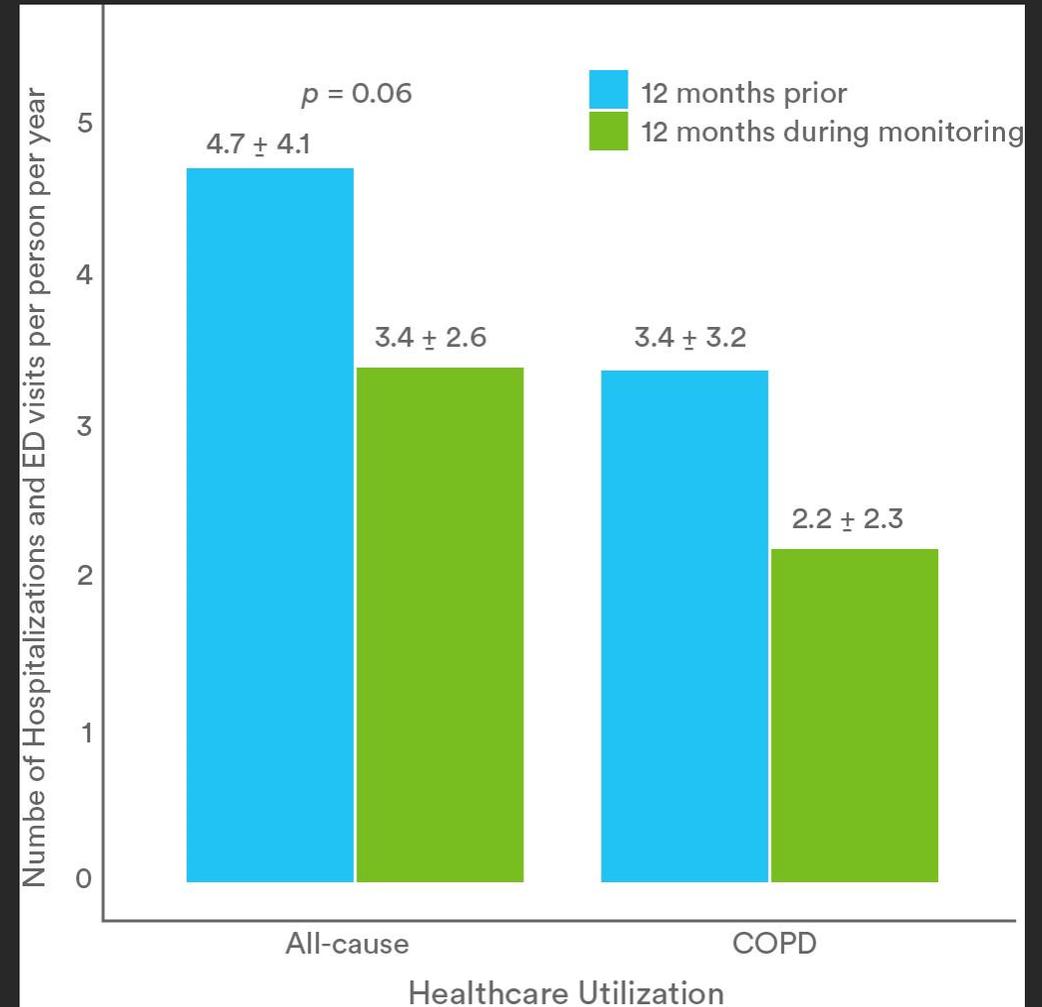
# Clinical outcomes (COPD): Decreased ED + hospital

## Study overview

Cleveland Clinic enrolled people into Propeller part of their routine clinical care and monitored for at least 1 year. Providers monitored SABA use and adherence to inhaled controller medications, and provided follow-up as needed.

## Population

- Patients with COPD with  $\geq 1$  utilization (ED visit or hospitalization) in prior 12 months
- N = 39; mean age: 69 years; 51% male; 69% African American; mean FEV<sub>1</sub> predicted: 47.2%; mean CAT 19



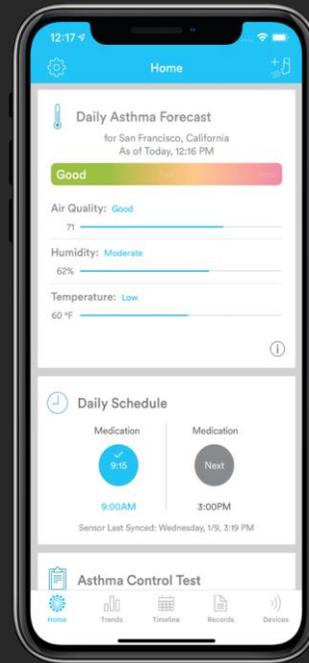
# How Propeller works

# What is Propeller?

Bluetooth-enabled sensors track rescue and controller medication use



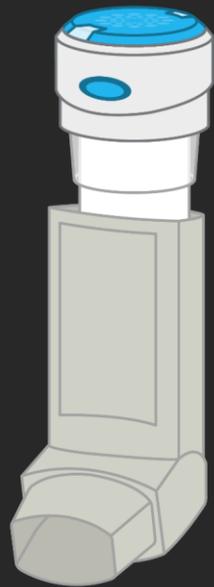
Passive syncing + patient/caregiver experiences



Objective data on medication adherence and clinical status for care teams



# Rescue use tracking and analysis



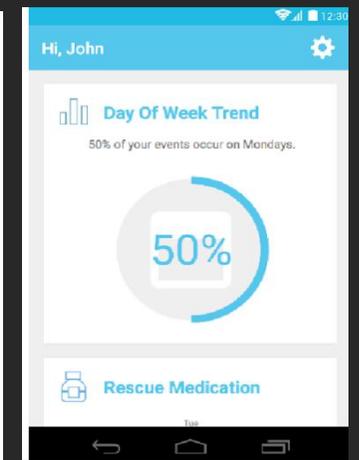
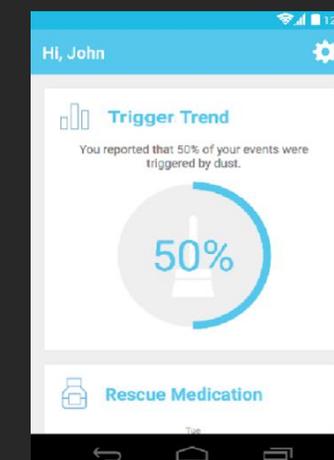
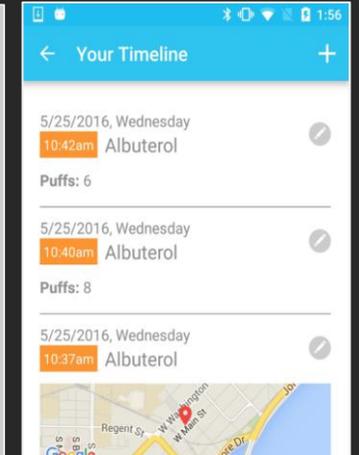
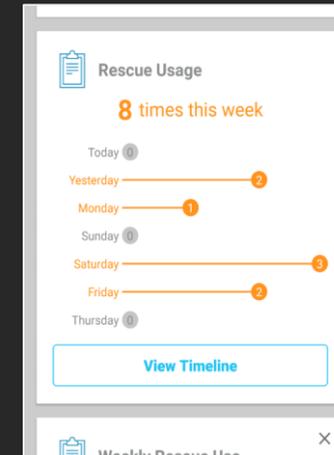
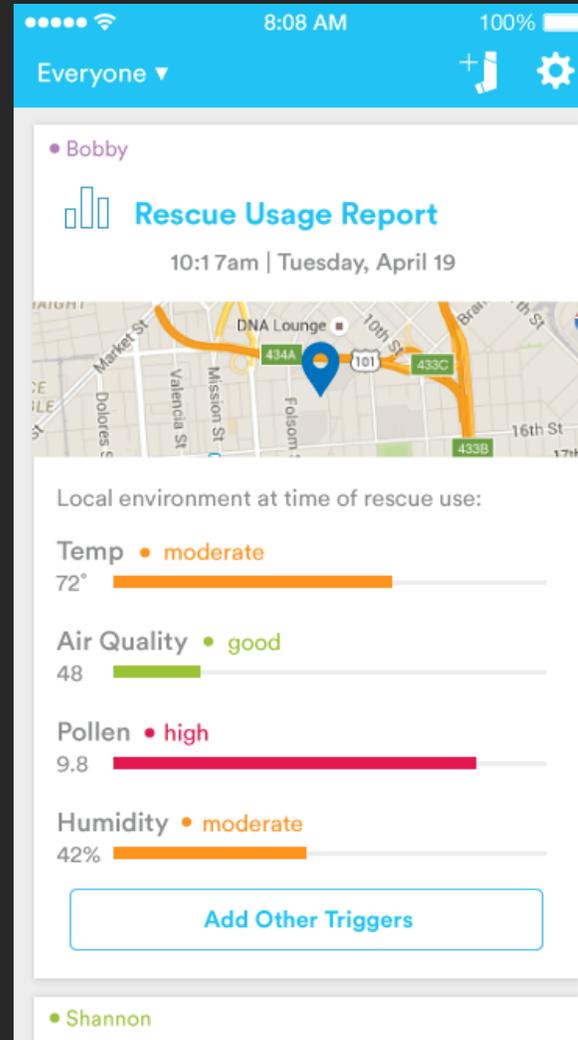
10:17:08 AM PST

AQI 48

47°34.4452 N,  
110°77.8257 W

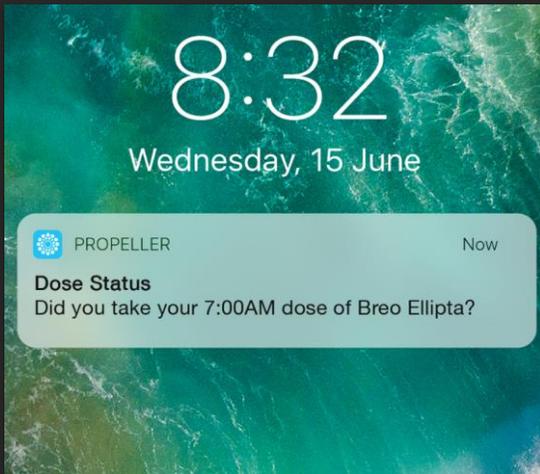
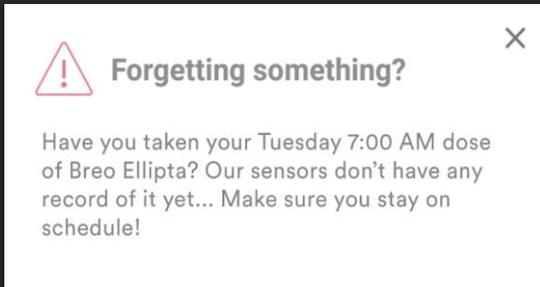
Winds from SW,  
13 mph

2 puffs of ProAir

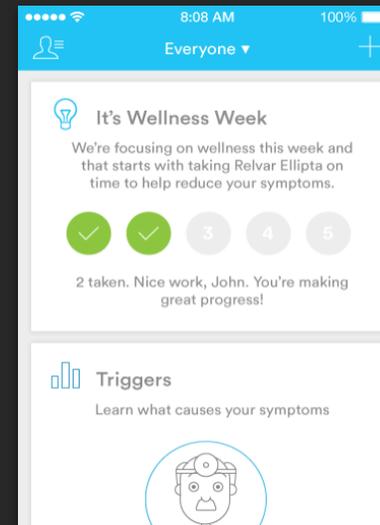
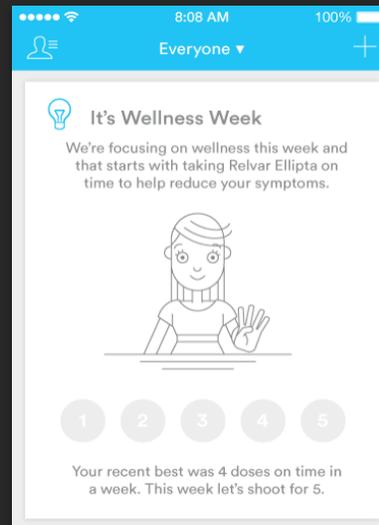


# Improving medication adherence

Propeller takes a multifaceted approach to help patients build sustainable medication-taking behaviors



In-app reminders



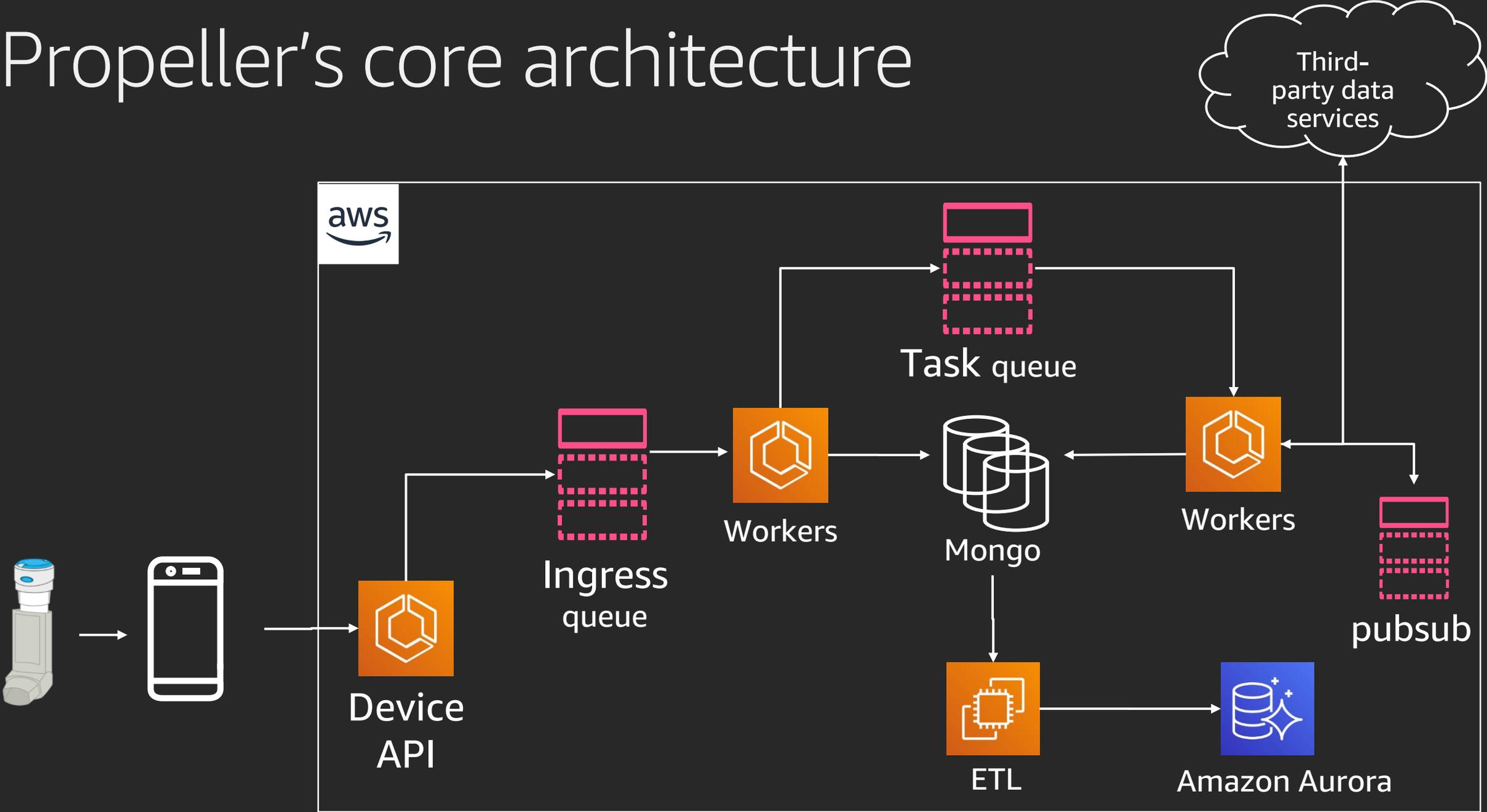
Game mechanics and behavior change





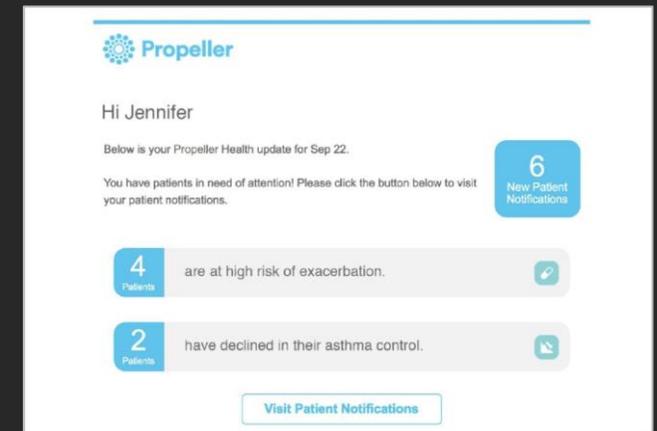
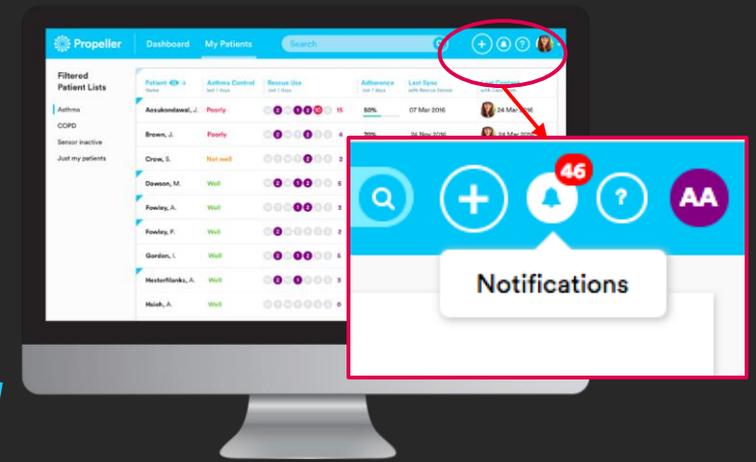
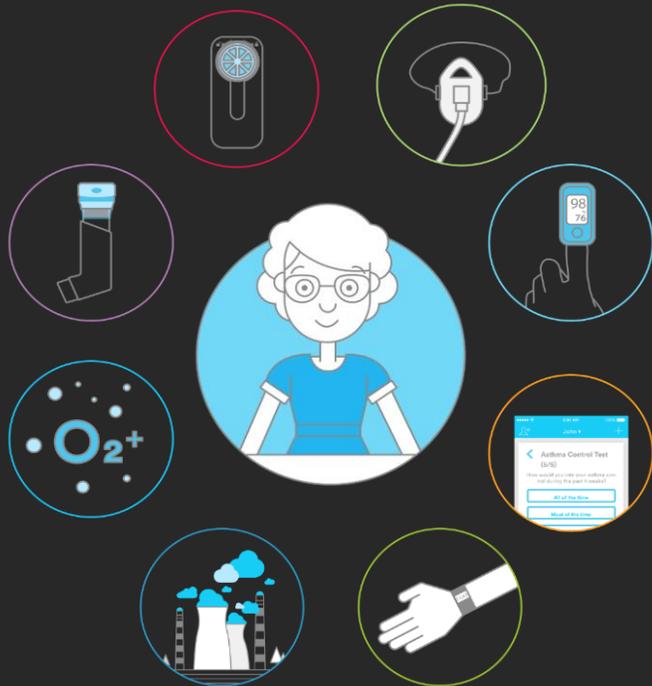
# Data infrastructure of Propeller

# Propeller's core architecture

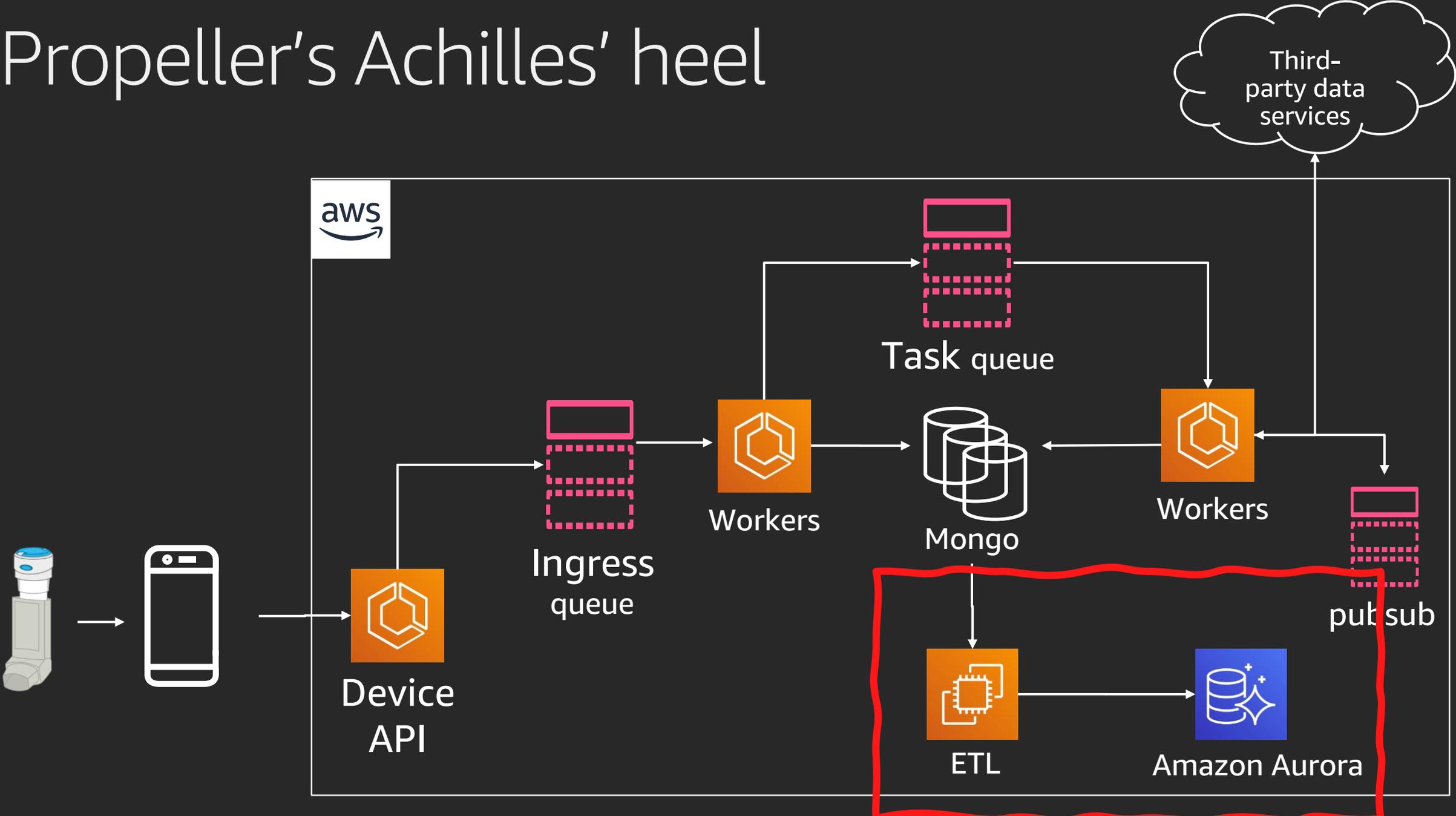


# Prediction models of large pools of patients

Propeller has developed algorithms and models to determine whether a patient is at increased risk for exacerbation

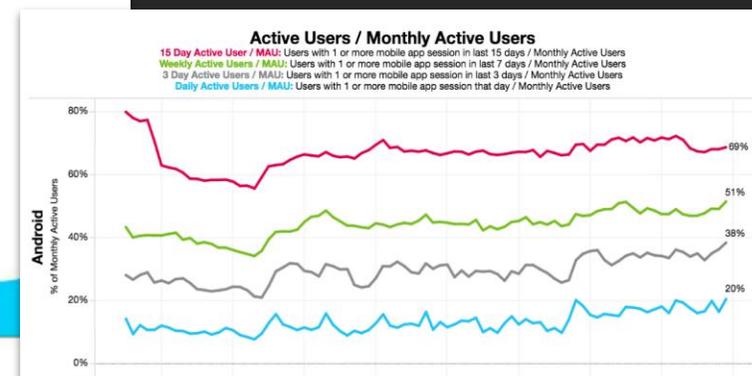
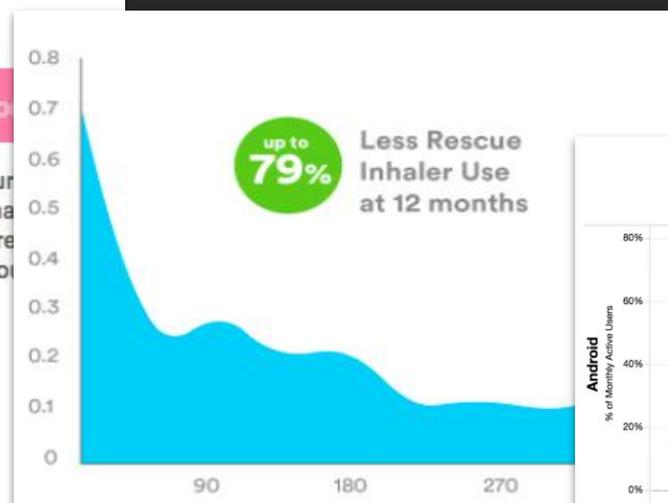
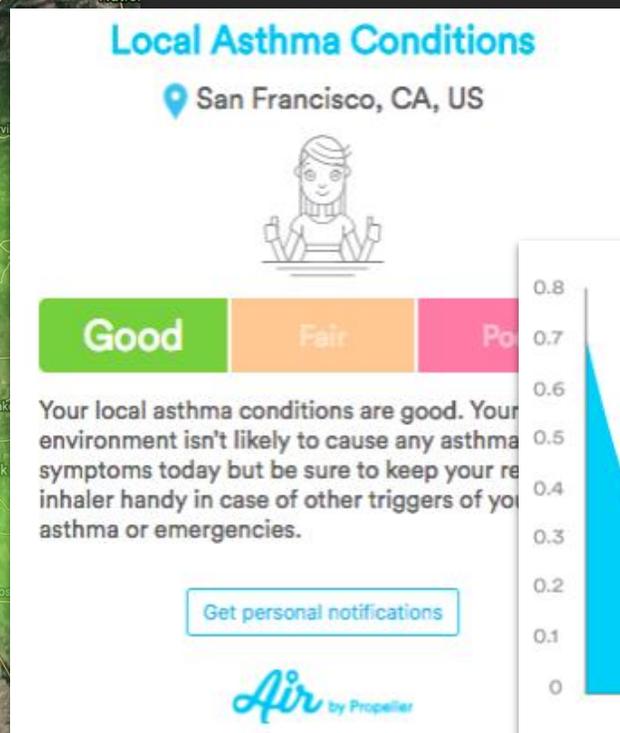
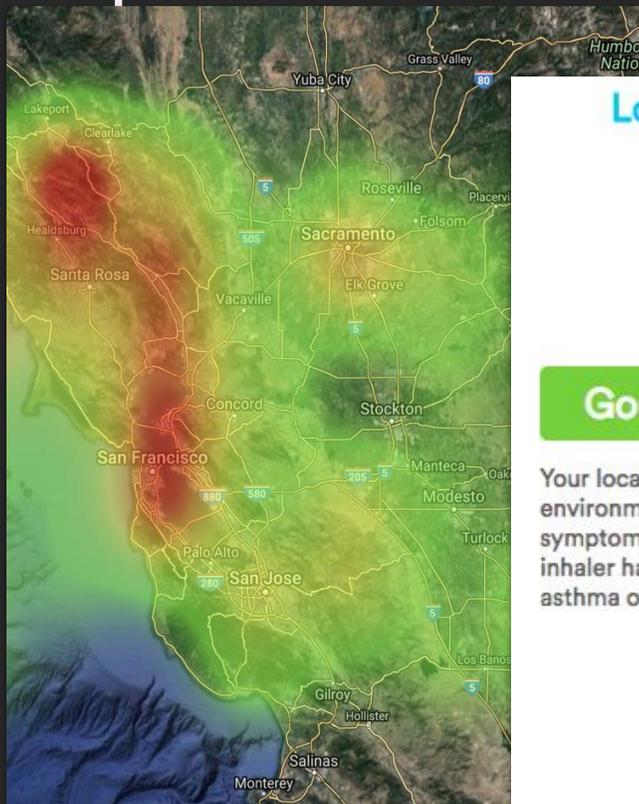


# Propeller's Achilles' heel



# Examples of analytics and data science capabilities

Propeller's data team provides partners with a wide range of capabilities including geospatial modeling of location and environment data, prediction modeling, clinical analytics, and continuous monitoring of product performance and user engagement



Geospatial modeling

Prediction models

Clinical analytics

Product insights

# Propeller's applied data infrastructure

Streams of app, web, patient, device, environmental, & location data



Data are collected in proprietary and third-party systems



Amazon S3



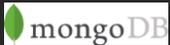
Data are extracted, transformed, and loaded into unstructured, semi-structured & structured data stores



Amazon Aurora



Amazon S3



Data science team uses a combination of tools to derive insights



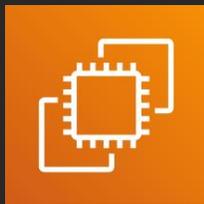
Modern machine learning tools are used to build models to power personalized experiences



# We're growing up



Mongo



ETL



Amazon Aurora



Analysts



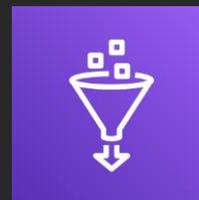
Propeller



Amazon Kinesis



Amazon S3



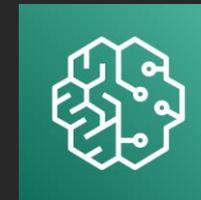
AWS Glue



Amazon Redshift

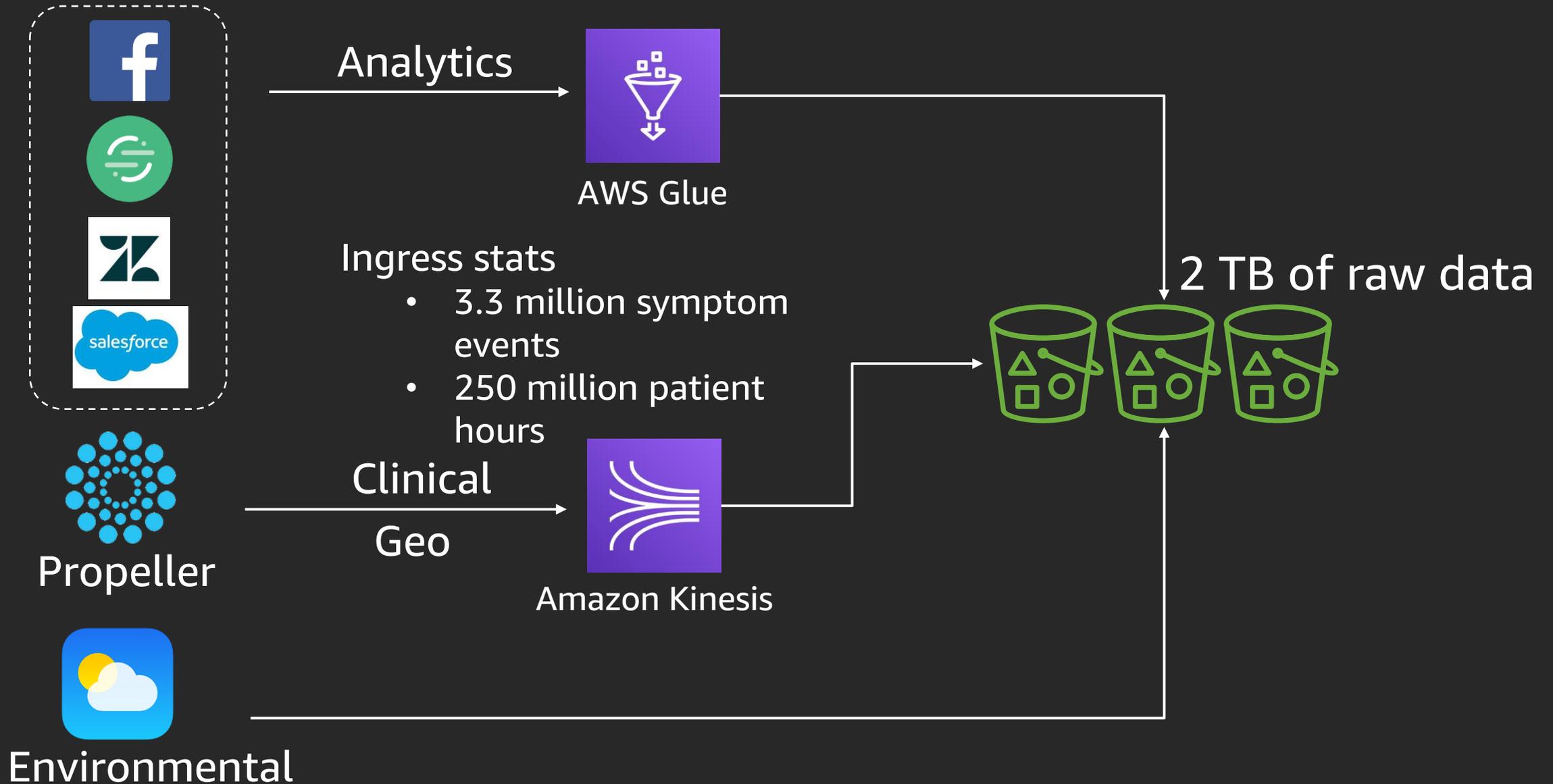


Looker reports

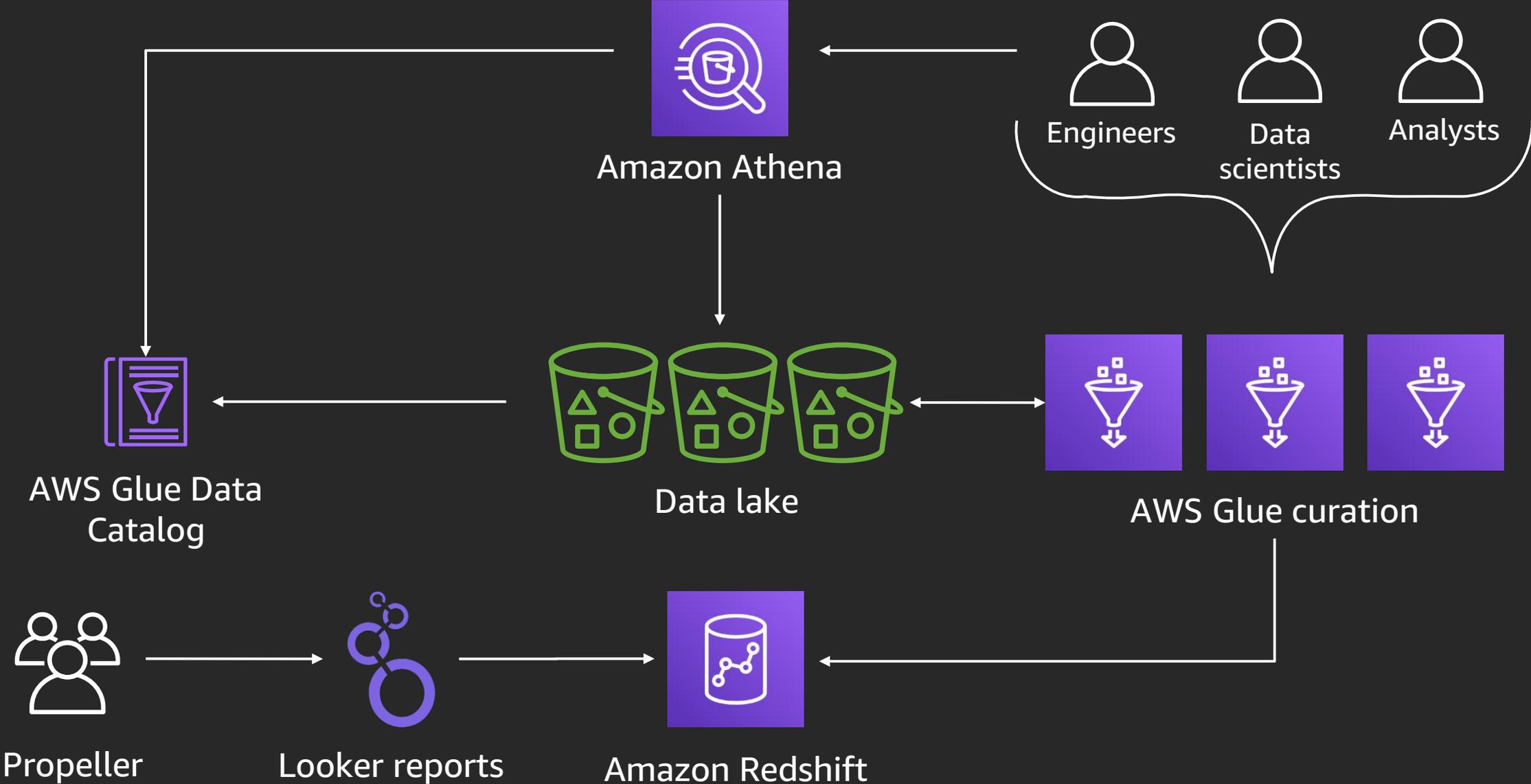


Amazon SageMaker

# Data lake architecture



# Enrich and transform

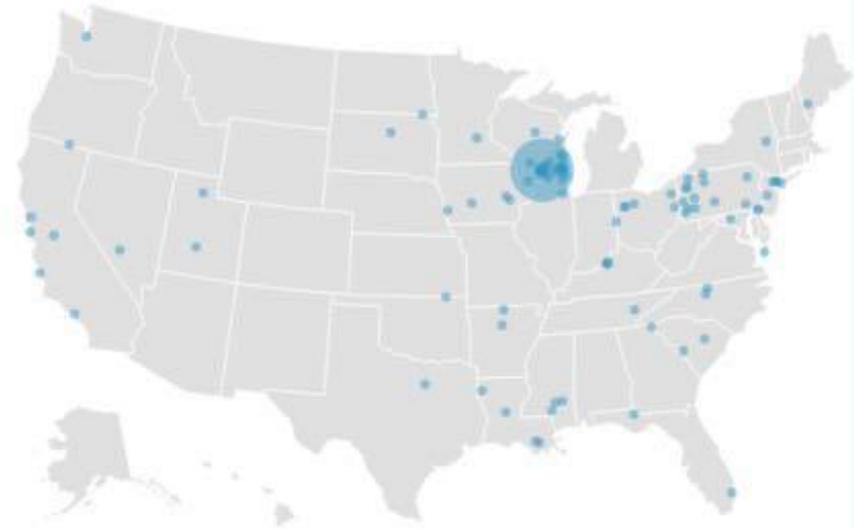


# Population-level reporting

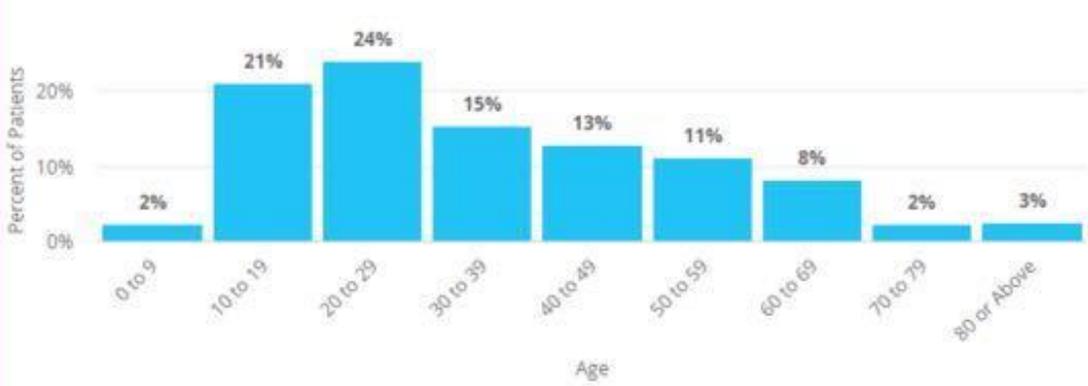
Onboarding



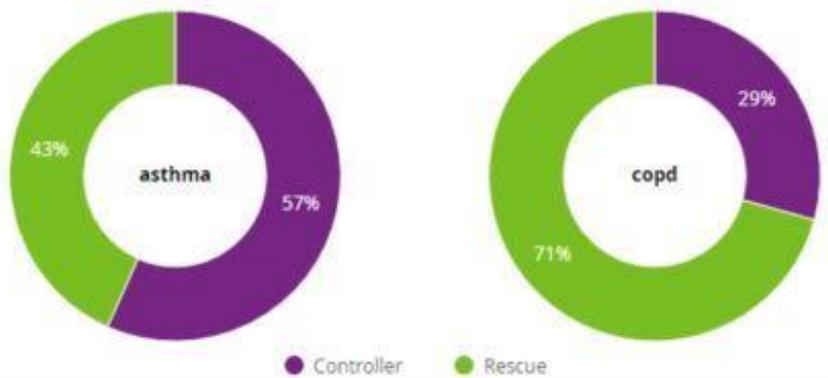
Patients by State



Patients by Age



Puffs by Medication Type



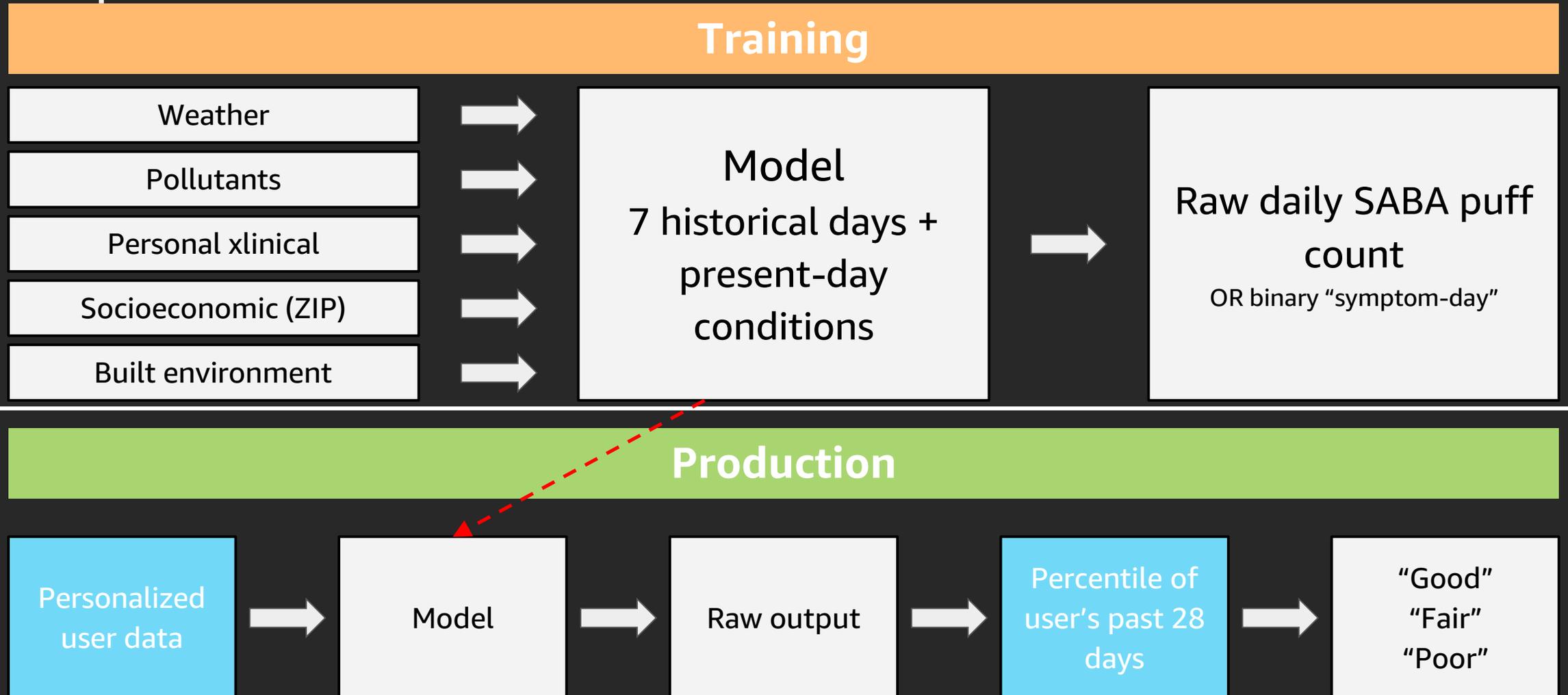
# Prediction models for individual patients

Providing actionable interventions to patients when we know that the conditions may be difficult

- Mobile push/email
  - Conditions are bad
  - Early morning
- Connect forecast to IFTTT
- Content in patient's feed

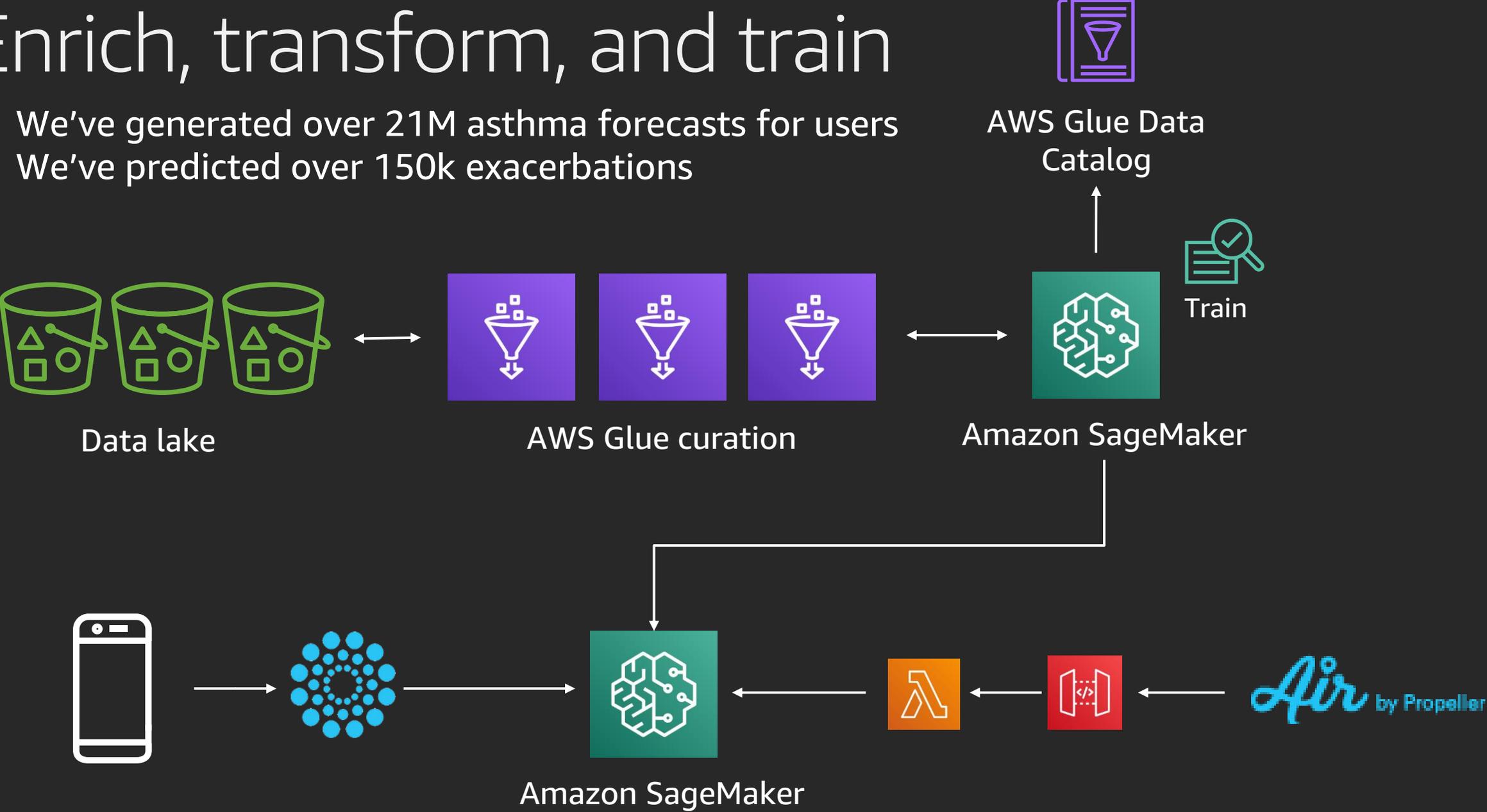
The image illustrates a multi-device health monitoring system. On the left, a smartphone displays a text message: "Asthma conditions in Madison, WI just changed to fair. Be sure to keep your rescue inhaler handy." In the center, a laptop screen shows the "Air by Propeller" website, which provides a "Daily Asthma Forecast" for San Francisco, CA, as of Jan 5 | 1:00 PM. The forecast indicates "Fair" air quality with a score of 90, "Midium" temperature at 70°F, "Midium" humidity at 55%, and "Low" levels for PM 2.5 and O3. On the right, a tablet displays a similar forecast interface, showing the current air quality as "Fair" and providing a detailed breakdown of environmental factors. A large green speech bubble in the background repeats the message: "Asthma conditions in Madison, WI just changed to fair. Be sure to keep your rescue inhaler handy."

# Our framework personalizes both inputs and outputs



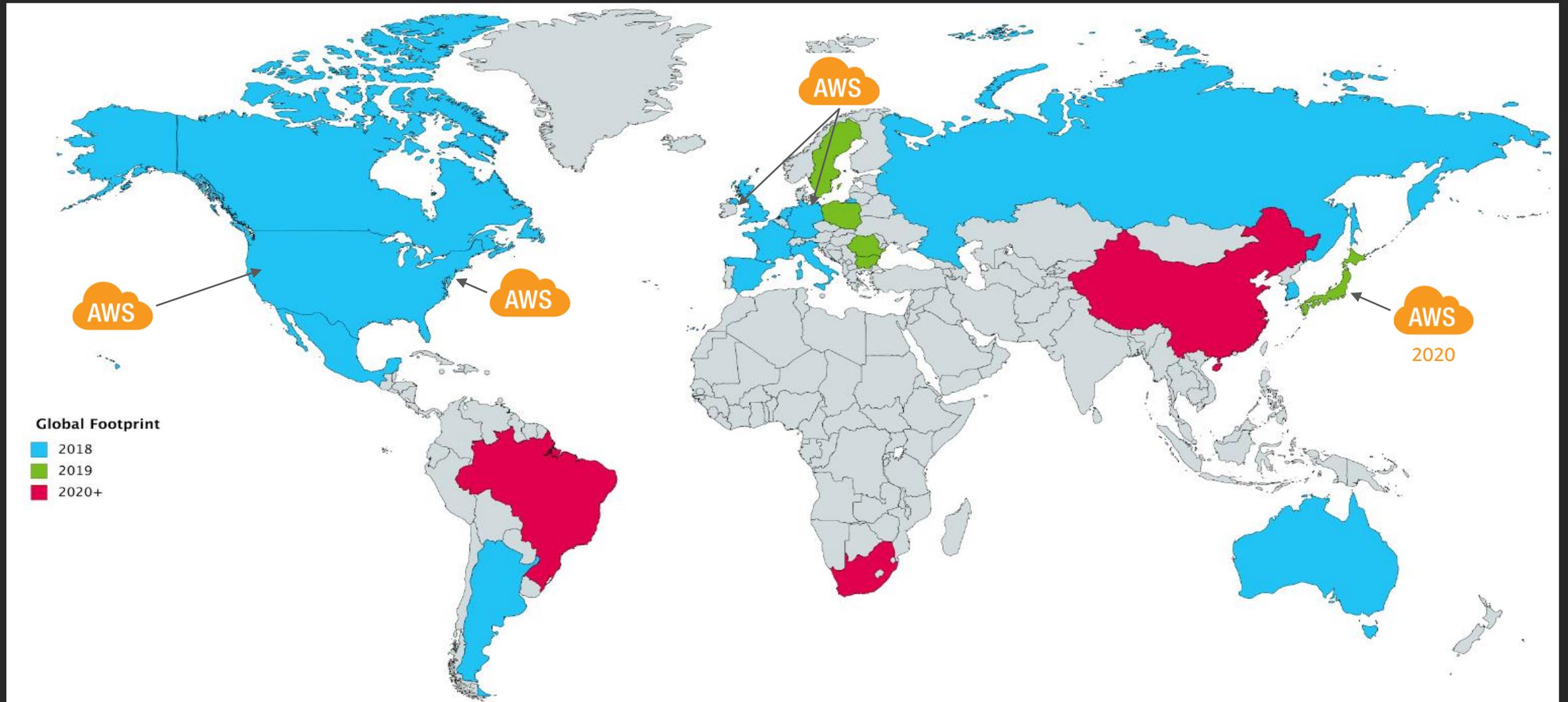
# Enrich, transform, and train

- We've generated over 21M asthma forecasts for users
- We've predicted over 150k exacerbations

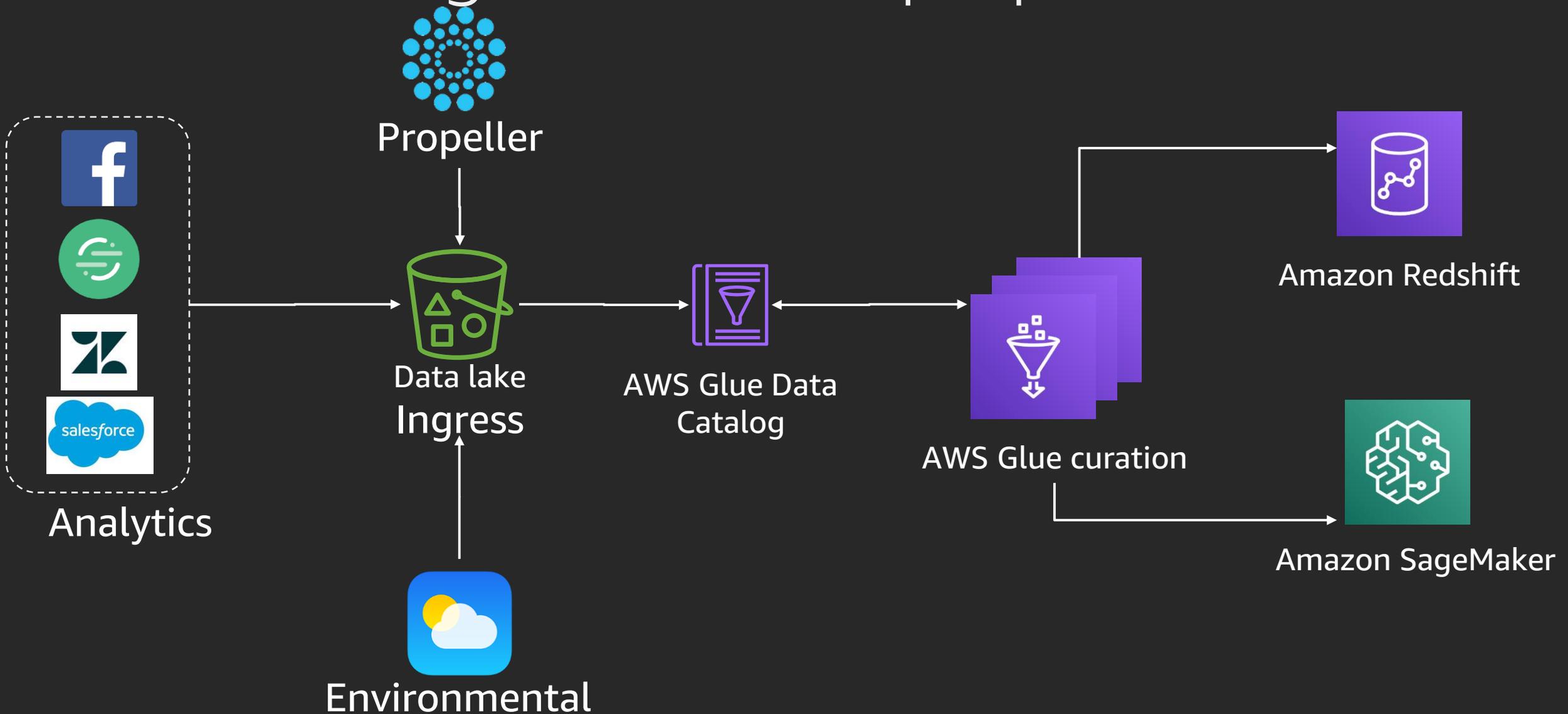


# Looking forward

# We're scaling and expanding



# We're feeling settled and prepared



# We're exploring new inputs and models

Inputs and outputs are personalized

The model itself is not

Prototyping, common sense, and evidence from other fields such as predictive maintenance suggest that simple, more personalized tree-based models outperform population-level deep learning models

Sensitivity  
similarity meta-  
model



Training/validation  
data from K most  
similar patients



Use previous  
framework with  
tree-based models

## Pipelines

- New datasets & signals
- Near-time predictions
- Per-patient automatic retraining
- Improve accuracy of existing datasets

## UX

- Less friction
- More education/context
- Bubble up raw signals

# Healthcare & Life Sciences networking lounge

**Join us** at our networking lounge  
for post-session speaker  
meet-and-greets, lightning talks,  
and informal discussions

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**Venetian, Level 3**



# AWS Healthcare & Life Sciences Happy Hour

**Join us** at our networking reception for informal discussions with industry colleagues and AWS HCLS Leadership

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**Tuesday:** 6:00 – 8:00 PM

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**OTORO Sushi & Grill @ Mirage Hotel**

# Thank you!



Please complete the session survey in the mobile app.