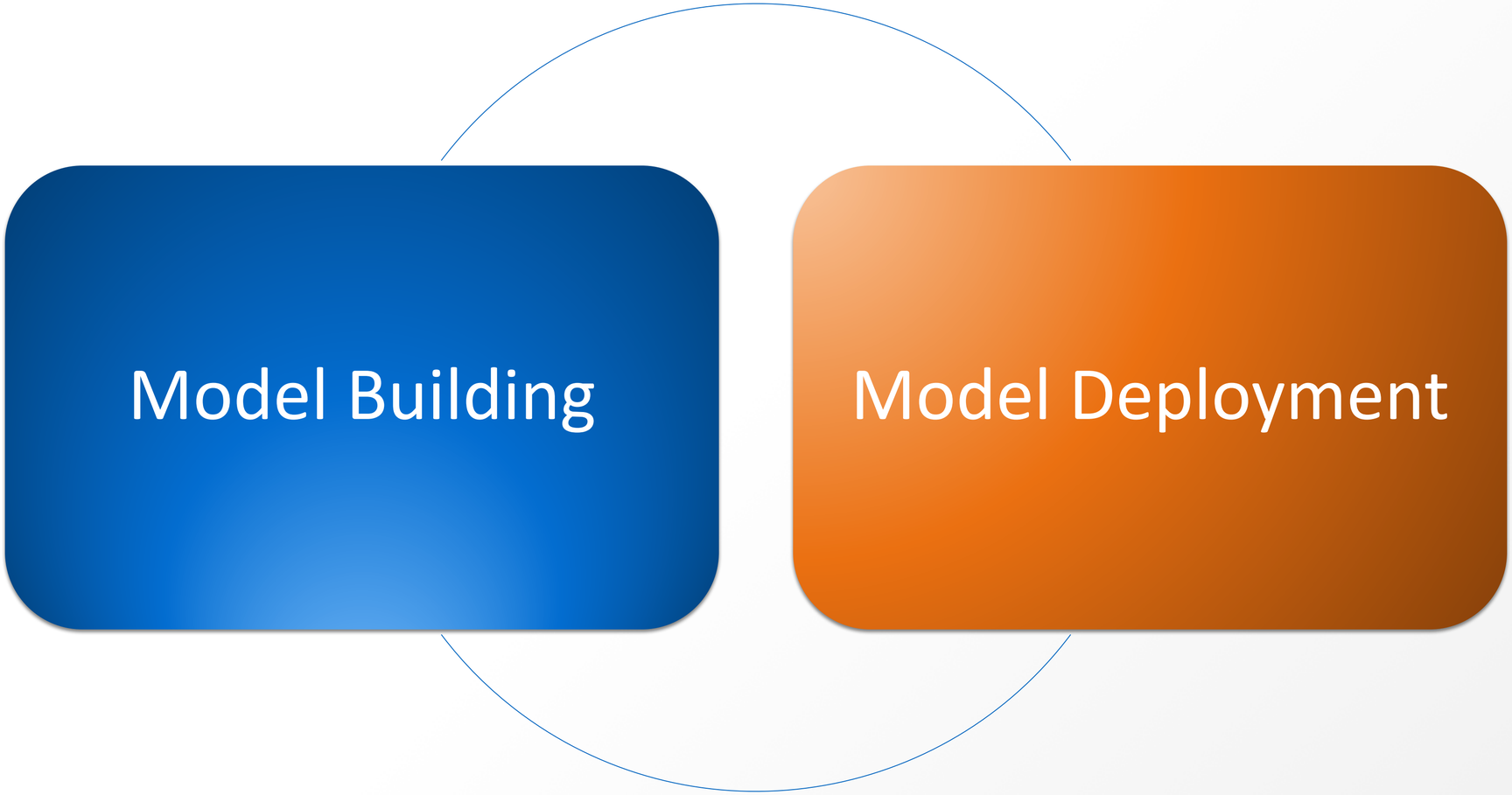
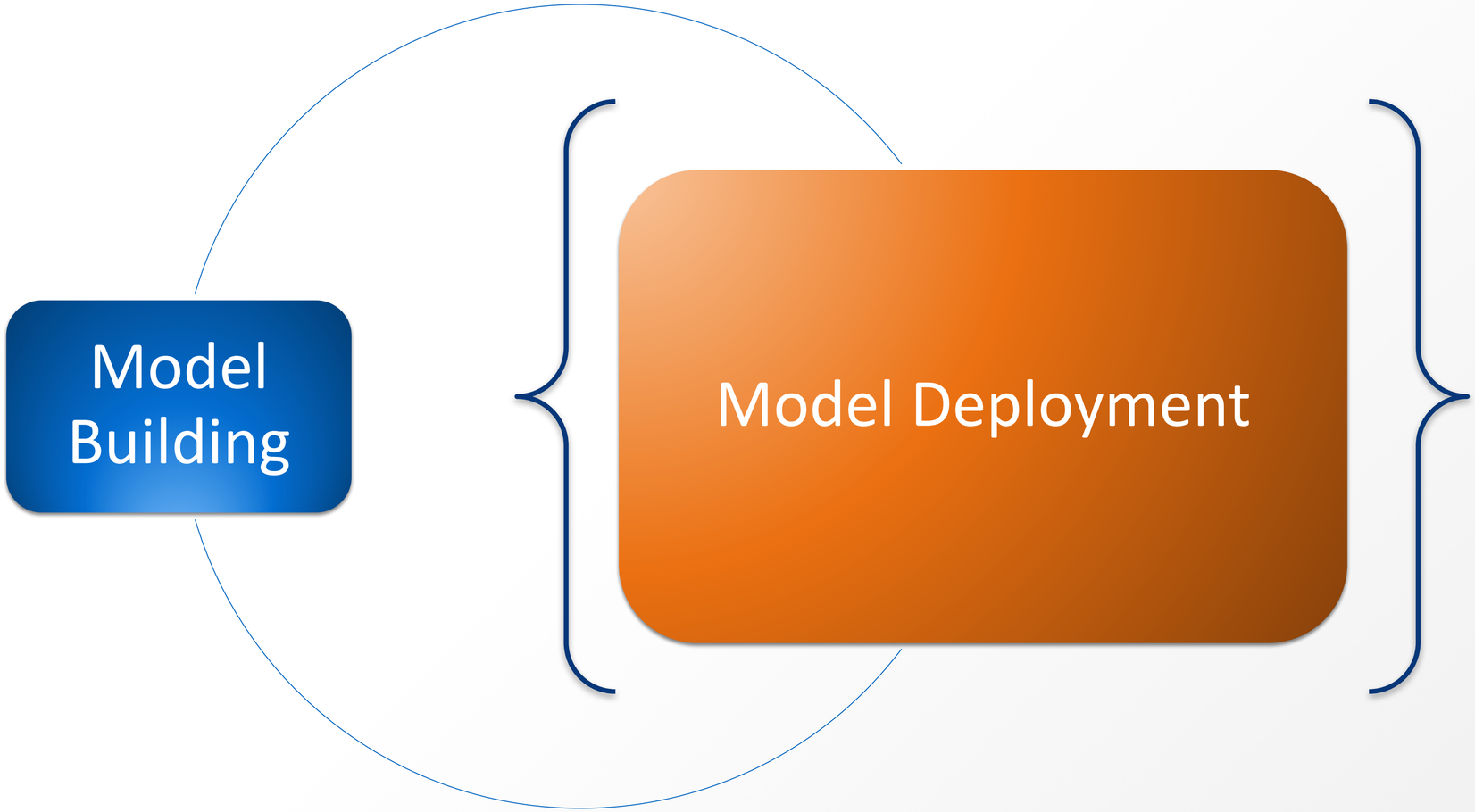
# Model Deployment in H2O
## (H2O Models in Production)

avkash@h2o.ai

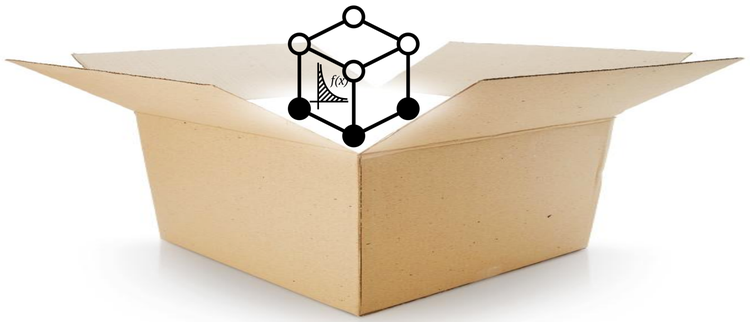
# Machine Learning Process

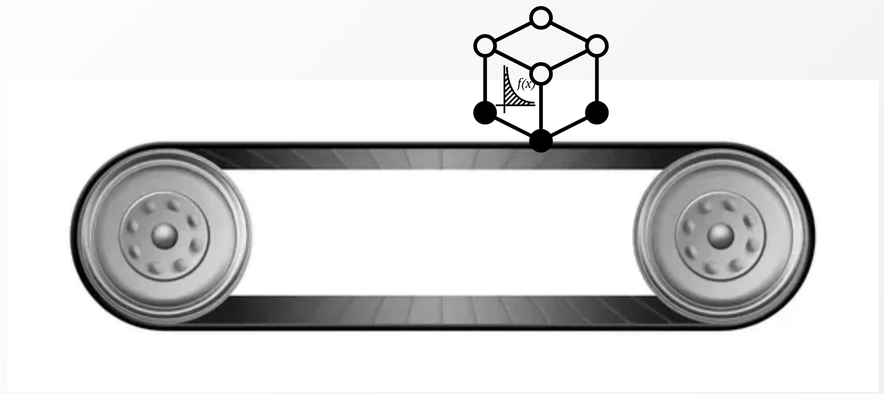


# Machine Learning Process

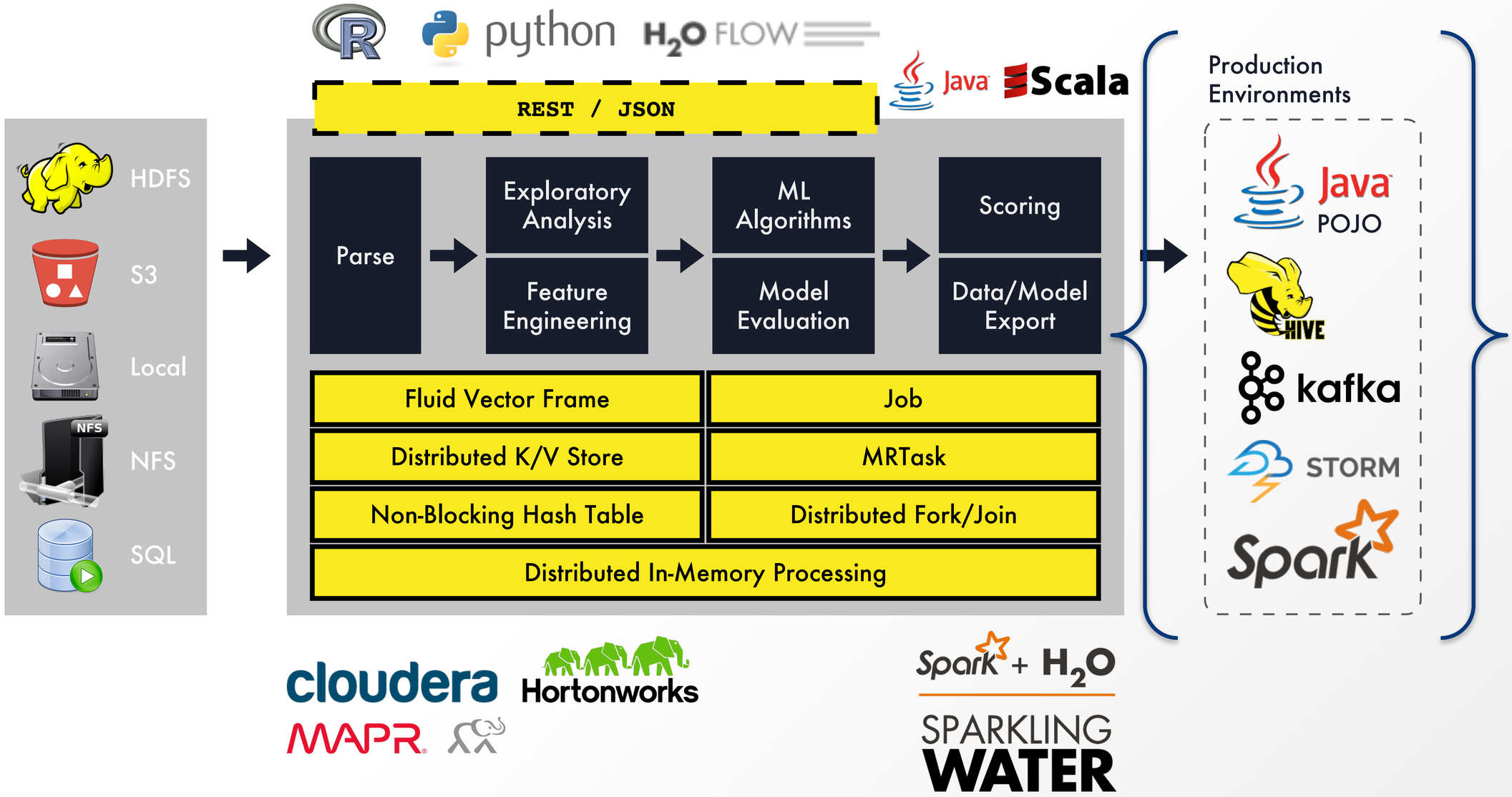


# So what is model deployment?





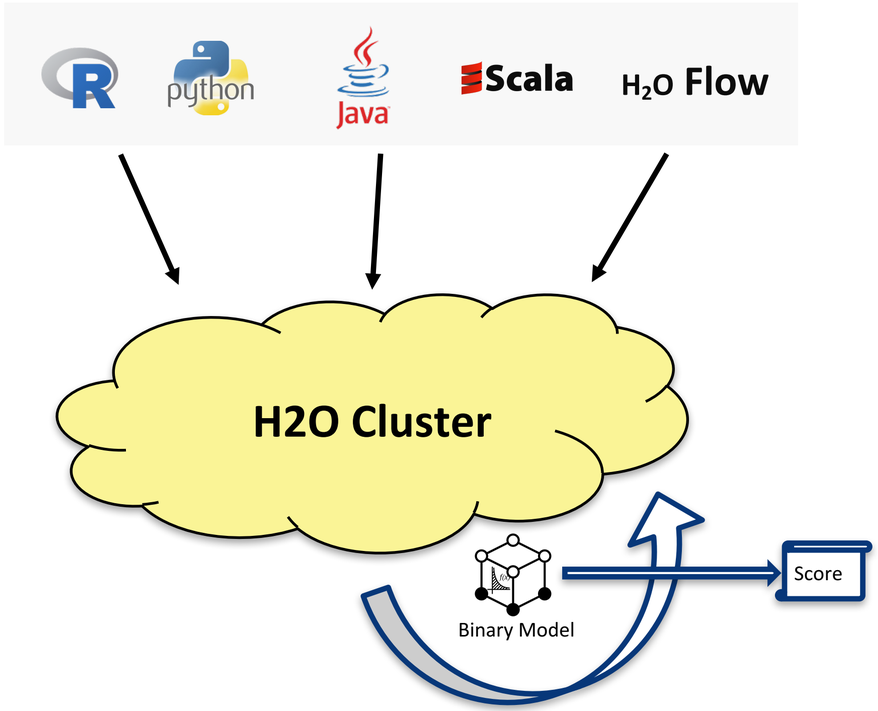
# Core H2O Architecture



# Model Deployment

- In-Cluster Scoring (Requires H2O cluster)
  - Binary Model
- Out-cluster Scoring (Independent to H2O)
  - Plain Old Java Object (POJO)
  - Model Object Optimized (MOJO)
    - Java MOJO
    - C++ MOJO

# Machine Learning Model Lifecycle




(H2O can run anywhere: desktop, cloud, on-prem;
Hadoop and Spark environments supported)

**Model Training**

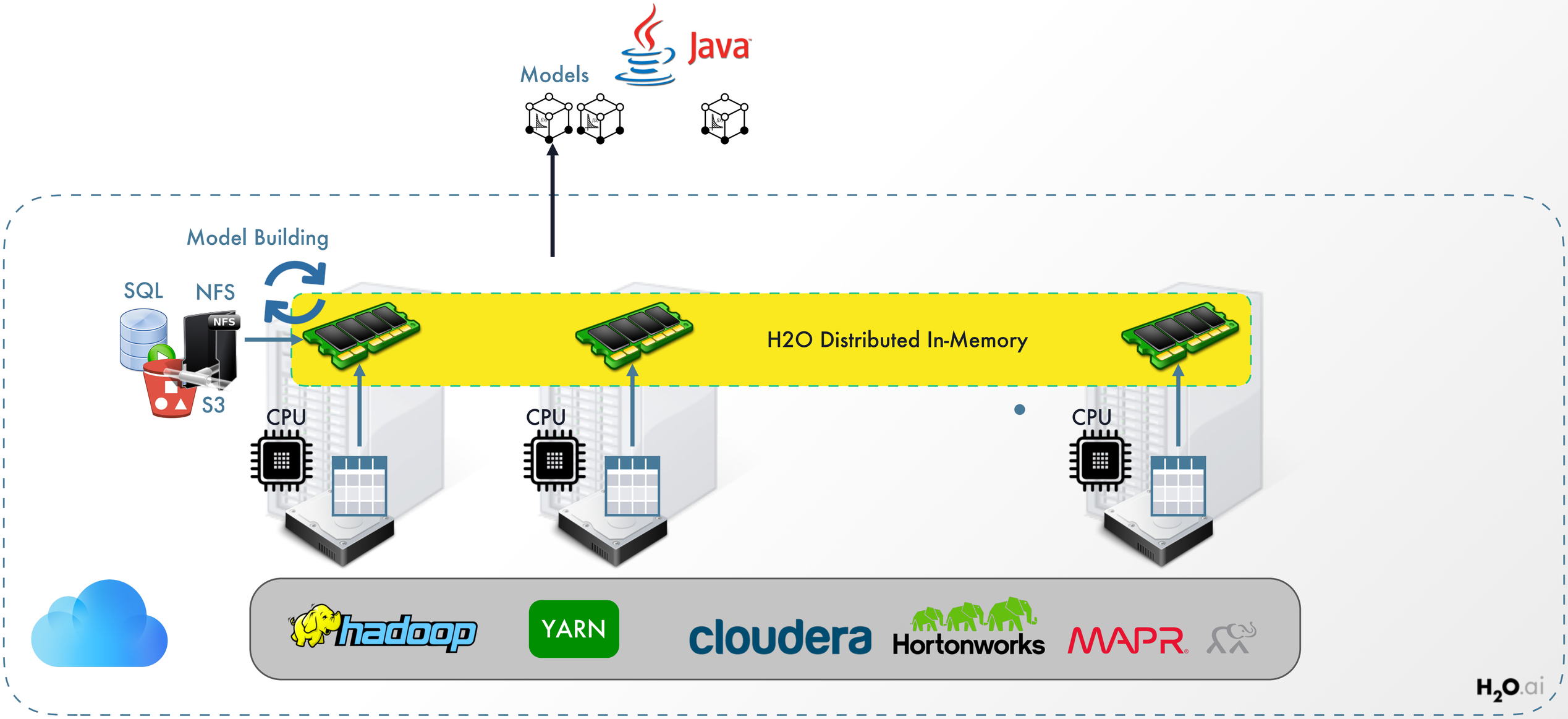
# In-Cluster Scoring

- Model Persistence

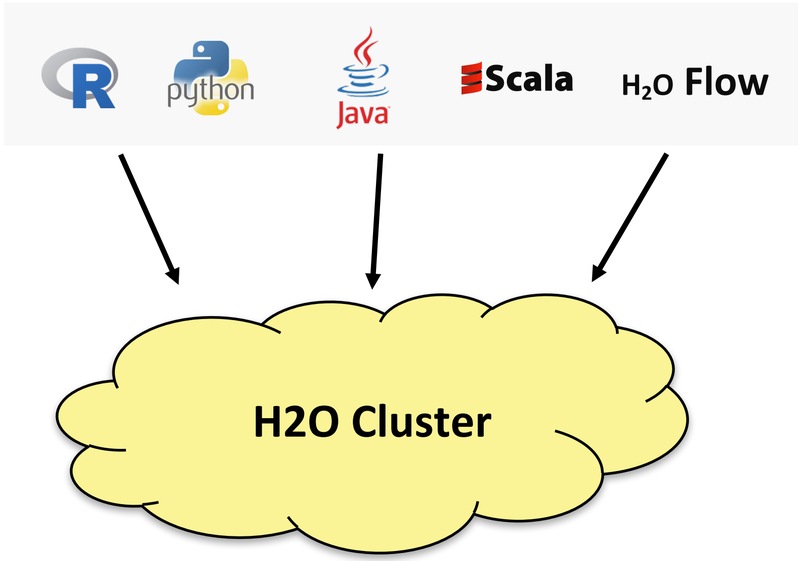
- R API
  - `h2o.saveModel(object, path, force=FALSE)`
  - `h2o.loadModel(path)`
  - `h2o.predict(object, newdata)`

- Python API
  - `h2o.save_model(model, path, force=False)`
  - `h2o.load_model(path)`
  - `H2OModel.predict(newdata)`

# Deployment Code



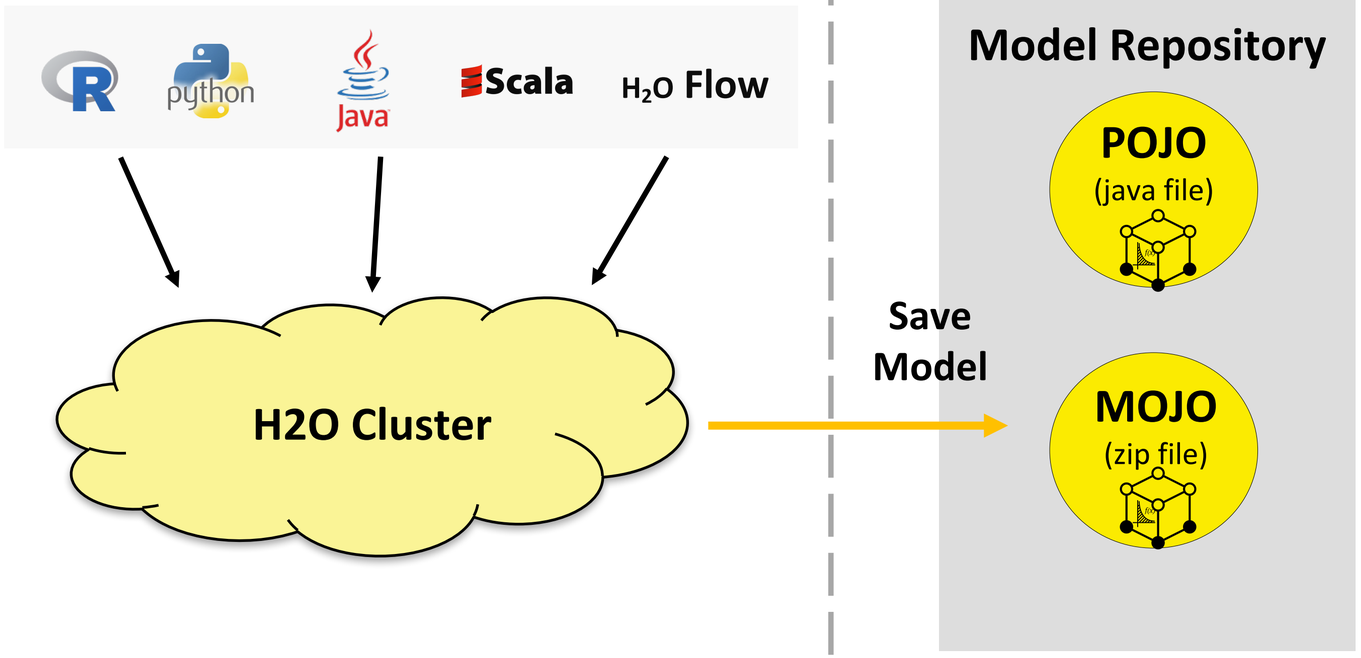
# Machine Learning Model Lifecycle




(H2O can run anywhere: desktop, cloud, on-prem;
Hadoop and Spark environments supported)

**Model Training**

# Machine Learning Model Lifecycle




(H2O can run anywhere: desktop, cloud, on-prem; Hadoop and Spark environments supported)

(Store models in H2O Steam, git, HDFS, S3, etc.)

**Model Training** → **Model Management**

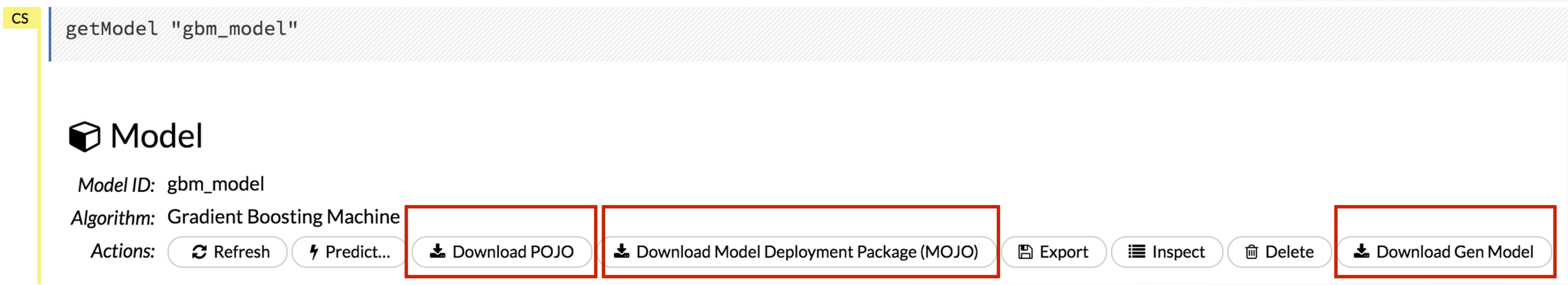
H2O

# What is POJO/MOJO

- Java Code file
  - POJO – Source Code
    - Source code managed
  - MOJO – Compressed Java
    - Un-redable as it is compressed
- H2O provides supported
  - H2o-genmodel.jar
    - Must required with both POJO and MOJO

# Exporting POJO/MOJO

- FLOW



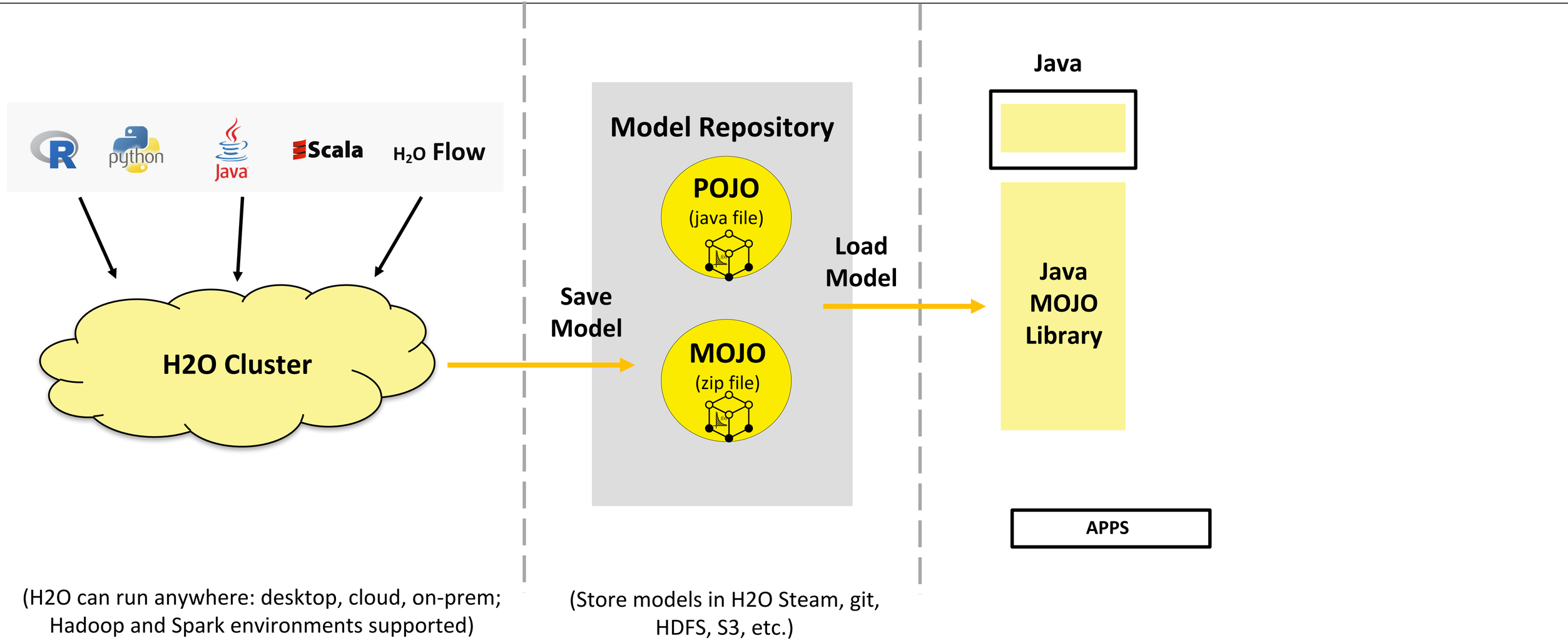

- R : The file system will be used for the environment where R is launched
  - h2o.download_mojo(gbm_model, path='/tmp/', get_genmodel_jar = TRUE)
  - h2o.download_pojo(gbm_model, path='/tmp/')

- Python: The file system will be used for the environment where R is launched
  - gbm_model.download_mojo(path='/tmp/', get_genmodel_jar=True)
  - gbm_model.download_pojo(path='/tmp/', get_genmodel_jar=True)

# Plain Old Java Object (POJO) Code

```
/*
  Licensed under the Apache License, Version 2.0
    http://www.apache.org/licenses/LICENSE-2.0.html

  AUTOGENERATED BY H2O at 2017-01-18T16:30:55.681-08:00
  3.10.2.2

  Standalone prediction code with sample test data for GBMModel named gbm_prostate

  How to download, compile and execute:
      mkdir tmpdir
      cd tmpdir
      curl http://10.0.1.13:54321/3/h2o-genmodel.jar > h2o-genmodel.jar
      curl http://10.0.1.13:54321/3/Models.java/gbm_prostate > gbm_prostate.java
      javac -cp h2o-genmodel.jar -J-Xmx2g -J-XX:MaxPermSize=128m gbm_prostate.java

     (Note:  Try java argument -XX:+PrintCompilation to show runtime JIT compiler behavior.)
*/
import java.util.Map;
import hex.genmodel.GenModel;
import hex.genmodel.annotations.ModelPojo;

@ModelPojo(name="gbm_prostate", algorithm="gbm")
public class gbm_prostate extends GenModel {
  public hex.ModelCategory getModelCategory() { return hex.ModelCategory.Binomial; }

  public boolean isSupervised() { return true; }
  public int nfeatures() { return 5; }
  public int nclasses() { return 2; }

  // Names of columns used by model.
  public static final String[] NAMES = NamesHolder_gbm_prostate.VALUES;
  // Number of output classes included in training data response column.
  public static final int NCLASSES = 2;
```

H2O


Java
Model Repository
POJO
(java file)
Load
Model
Java
MOJO
Library
Save
Model
MOJO
(zip file)
H2O Cluster
APPS
(H2O can run anywhere: desktop, cloud, on-prem;
Hadoop and Spark environments supported)
(Store models in H2O Steam, git,
HDFS, S3, etc.)
Model Training
Model Management
Model Deployment

# POJO vs MOJO

| | Java POJO | MOJO / Java Runtime |
|---|---|---|
| **LANGUAGES** | • Java | • Java |
| **ALGORITHMS** | • All | • GLM, DRF, GBM, GLRM (but eventually all) |
| **COMPILING** | • Compiled<br>• Large POJO Compilation Errors | • Interpreted<br>• No compile errors |
| **CLASS LOADING** | • Java class loading issues for many models — must tune MaxPermSize | • No Java class loading issues (very few fixed number of classes) |
| **ALLOCATION** | • Models use PermGen storage | • Models stored in the Java heap |
| **PERFORMANCE** | • Faster for small trees (about 1.5x-2x) | • Faster for large trees (about 20x) |
| **BACKWARD COMPATIBILITY** | • POJO genmodel backward compatibility unsupported<br>• Difficult to run old and new versions side-by-side (requires multiple library versions and classloading tricks) | • Strong MOJO genmodel backward compatibility<br>• Easy to run old and new versions side-by-side<br>• Same prediction results with future genmodels for a saved MOJO |
| **SIZE** | • ~10x larger than MOJO, so ~10x larger than .zip file | • Size is 1/10th of a POJO |
| **EASY WRAPPER** | • Works with Java EasyPredict API | • Works with Java EasyPredict API |
| **DECISION VISIBILITY** | • Decisions are visible in generated code | • Opaque (but open source) binary format<br>• Visualization tools provided (e.g. tree viewer) |

# POJO – main.java sample for regression

```java
import java.io.*;
import java.util.Arrays;
import hex.genmodel.easy.RowData;
import hex.genmodel.easy.EasyPredictModelWrapper;
import hex.genmodel.easy.prediction.*;

public class main {
  private static String modelClassName = "glm_model";

  public static void main(String[] args) throws Exception {

    hex.genmodel.GenModel rawModel;
    rawModel = (hex.genmodel.GenModel) Class.forName(modelClassName).newInstance();

    System.out.println("isSupervised : " + rawModel.isSupervised());
    System.out.println("Model UUID : " + rawModel.getUUID());
    System.out.println("Column Names : " + Arrays.toString(rawModel.getNames()));
    System.out.println("Response ID : " + rawModel.getResponseIdx());
    System.out.println("Number of columns : " + rawModel.getNumCols());
    //System.out.println("Response Name : " + rawModel.getResponseName());
    System.out.println("isClassifier : " + rawModel.isClassifier());
    if (rawModel.isClassifier()) {
      System.out.println("Response Classes : " + rawModel.getNumResponseClasses());
    }

    for (int i = 0; i < rawModel.getNumCols(); i++) {
      String[] domainValues = rawModel.getDomainValues(i);
      System.out.println(Arrays.toString(domainValues));
    }

    EasyPredictModelWrapper model = new EasyPredictModelWrapper(rawModel);


    RowData row = new RowData();
    row.put("AGE", "68");
    row.put("RACE", "2");
    row.put("DCAPS", "2");
    row.put("VOL", "0");
    row.put("GLEASON", "6");

    RegressionModelPrediction p = model.predictRegression(row);
    System.out.println("Values: " + p.value);
    System.out.println("");
  }
}
```

H2O.ai

# POJO – main.java sample for classification

```java
import java.io.*;
import java.util.Arrays;
import hex.genmodel.easy.RowData;
import hex.genmodel.easy.EasyPredictModelWrapper;
import hex.genmodel.easy.prediction.*;

public class main {
  private static String modelClassName = "gbm_model";

  public static void main(String[] args) throws Exception {

    hex.genmodel.GenModel rawModel;
    rawModel = (hex.genmodel.GenModel) Class.forName(modelClassName).newInstance();

    System.out.println("isSupervised : " + rawModel.isSupervised());
    System.out.println("Column Names : " + Arrays.toString(rawModel.getNames()));
    System.out.println("Response ID : " + rawModel.getResponseIdx());
    System.out.println("Number of columns : " + rawModel.getNumCols());
    //System.out.println("Response Name : " + rawModel.getResponseName());
    for (int i = 0; i < rawModel.getNumCols(); i++) {
      String[] domainValues = rawModel.getDomainValues(i);
      System.out.println(Arrays.toString(domainValues));
    }

    EasyPredictModelWrapper model = new EasyPredictModelWrapper(rawModel);
    RowData row = new RowData();
    row.put("AGE", "68");
    row.put("RACE", "2");
    row.put("DCAPS", "2");
    row.put("VOL", "0");
    row.put("GLEASON", "6");

    BinomialModelPrediction p = model.predictBinomial(row);
    System.out.println("Has penetrated the prostatic capsule (1=yes; 0=no): " + p.label);
    System.out.print("Class probabilities: ");
    for (int i = 0; i < p.classProbabilities.length; i++) {
      if (i > 0) {
  System.out.print(",");
      }
      System.out.print(p.classProbabilities[i]);
    }
    System.out.println("");
  }
}
```

# MOJO – main.java sample for Regression

```java
import java.io.*;
import hex.genmodel.easy.RowData;
import hex.genmodel.easy.EasyPredictModelWrapper;
import hex.genmodel.easy.prediction.*;
import hex.genmodel.MojoModel;
import java.util.Arrays;

public class main {
  public static void main(String[] args) throws Exception {
    EasyPredictModelWrapper model = new EasyPredictModelWrapper(MojoModel.load("glm_model.zip"));

    RowData row = new RowData();
    row.put("AGE", "68");
    row.put("RACE", "2");
    row.put("DCAPS", "2");
    row.put("VOL", "0");
    row.put("GLEASON", "6");

    RegressionModelPrediction p = model.predictRegression(row);
    System.out.println("Values: " + p.value);
    System.out.println("");
  }
}
```

# MOJO – main.java sample for Classification

```
import java.io.*;
import hex.genmodel.easy.RowData;
import hex.genmodel.easy.EasyPredictModelWrapper;
import hex.genmodel.easy.prediction.*;
import hex.genmodel.MojoModel;
import java.util.Arrays;

public class main {
  public static void main(String[] args) throws Exception {
    EasyPredictModelWrapper model = new EasyPredictModelWrapper(MojoModel.load("gbm_model.zip"));

     RowData row = new RowData();
    row.put("AGE", "68");
    row.put("RACE", "2");
    row.put("DCAPS", "2");
    row.put("VOL", "0");
    row.put("GLEASON", "6");

    BinomialModelPrediction p = model.predictBinomial(row);
    System.out.println("Has penetrated the prostatic capsule (1=yes; 0=no): " + p.label);
    System.out.print("Class probabilities: ");
    for (int i = 0; i < p.classProbabilities.length; i++) {
      if (i > 0) {
    System.out.print(",");
      }
      System.out.print(p.classProbabilities[i]);
    }
    System.out.println("");
 }
}
```

# Java Prediction Examples

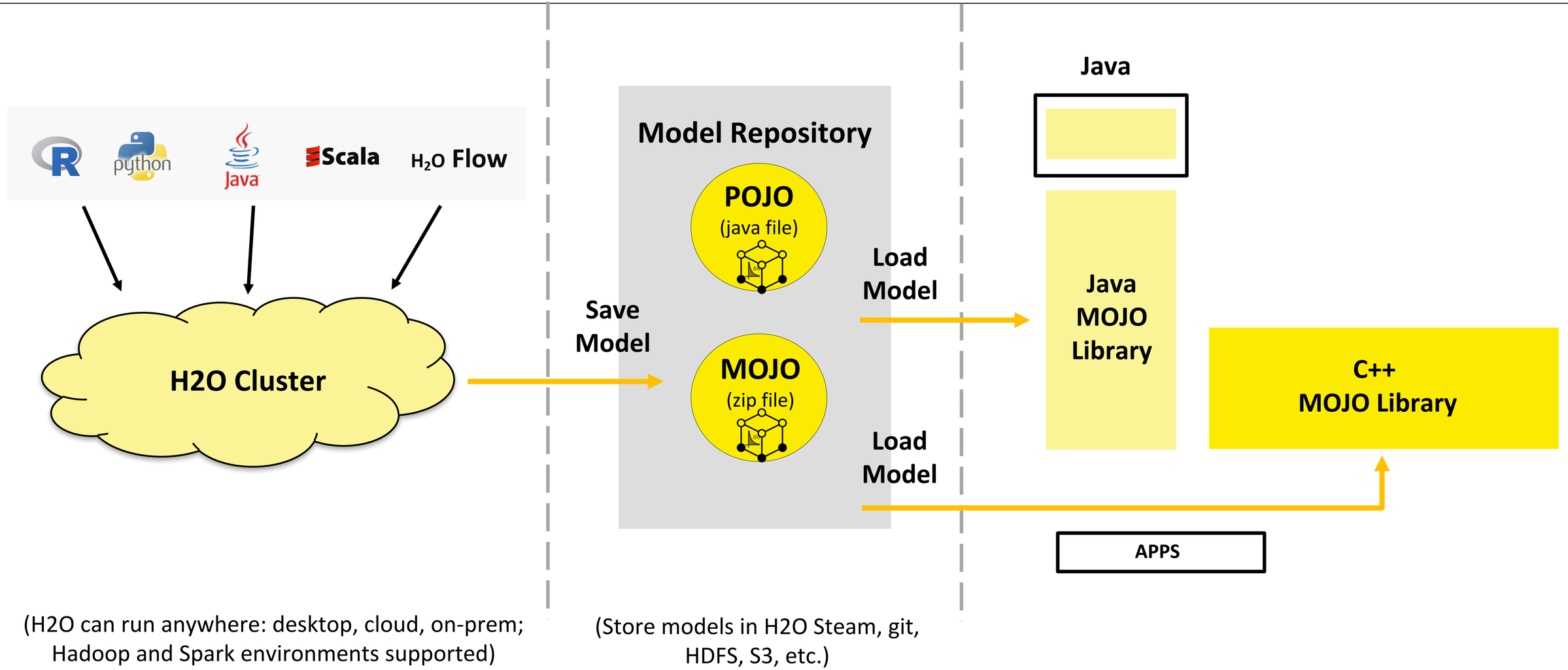
- POJO
  - Compile:
    - `$ javac -cp h2o-genmodel.jar -J-Xmx2g -J-XX:MaxPermSize=128m gbm_prostate.java main.java`
  - Run:
    - `$ java -cp .:h2o-genmodel.jar main`

- MOJO
  - Compile:
    - `$ javac -cp h2o-genmodel.jar -J-Xmx2g -J-XX:MaxPermSize=128m main.java`
  - Run:
    - `$ java -cp .:h2o-genmodel.jar main`

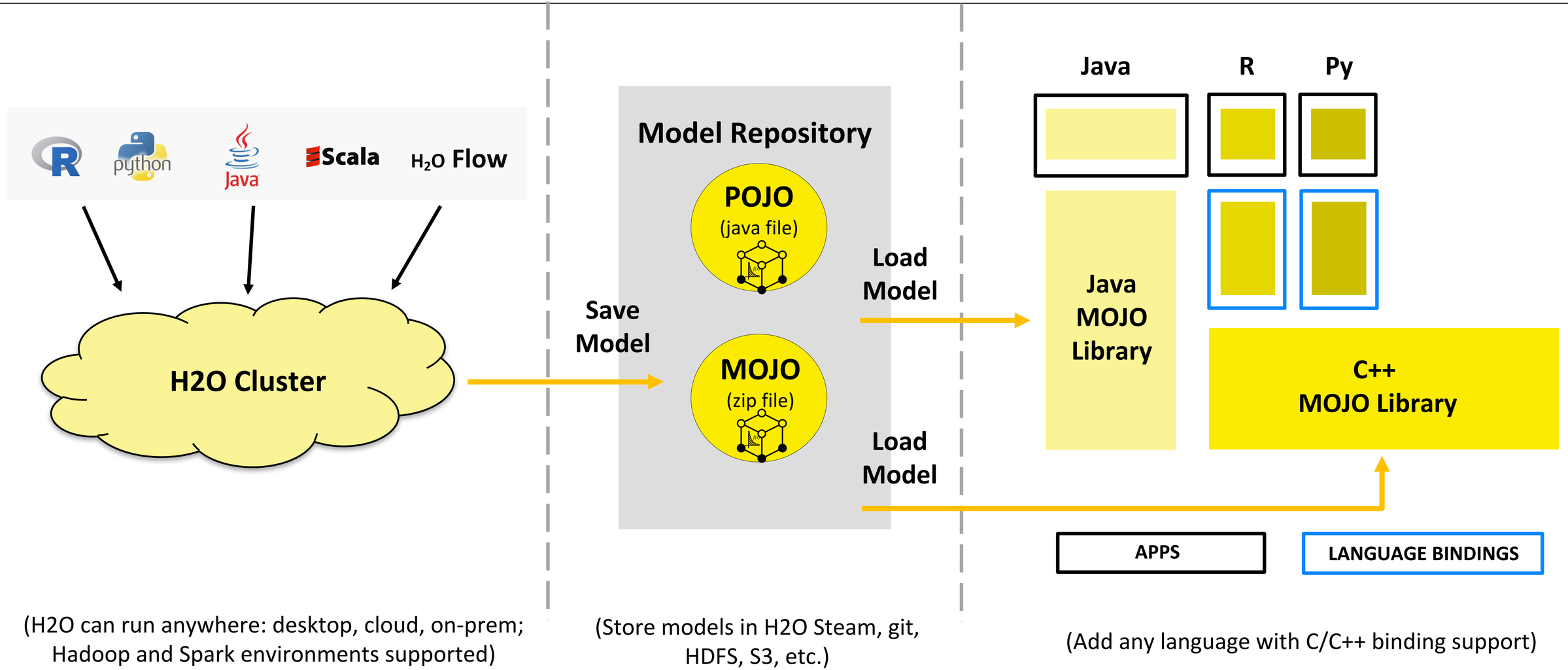
# Python MOJO Scoring

- Look or the API
  - Available into H2O 3.14.0.3 onwards ONLY
  - H2o.predict_json()

# Machine Learning Model Lifecycle



# Machine Learning Model Lifecycle




(H2O can run anywhere: desktop, cloud, on-prem; Hadoop and Spark environments supported)

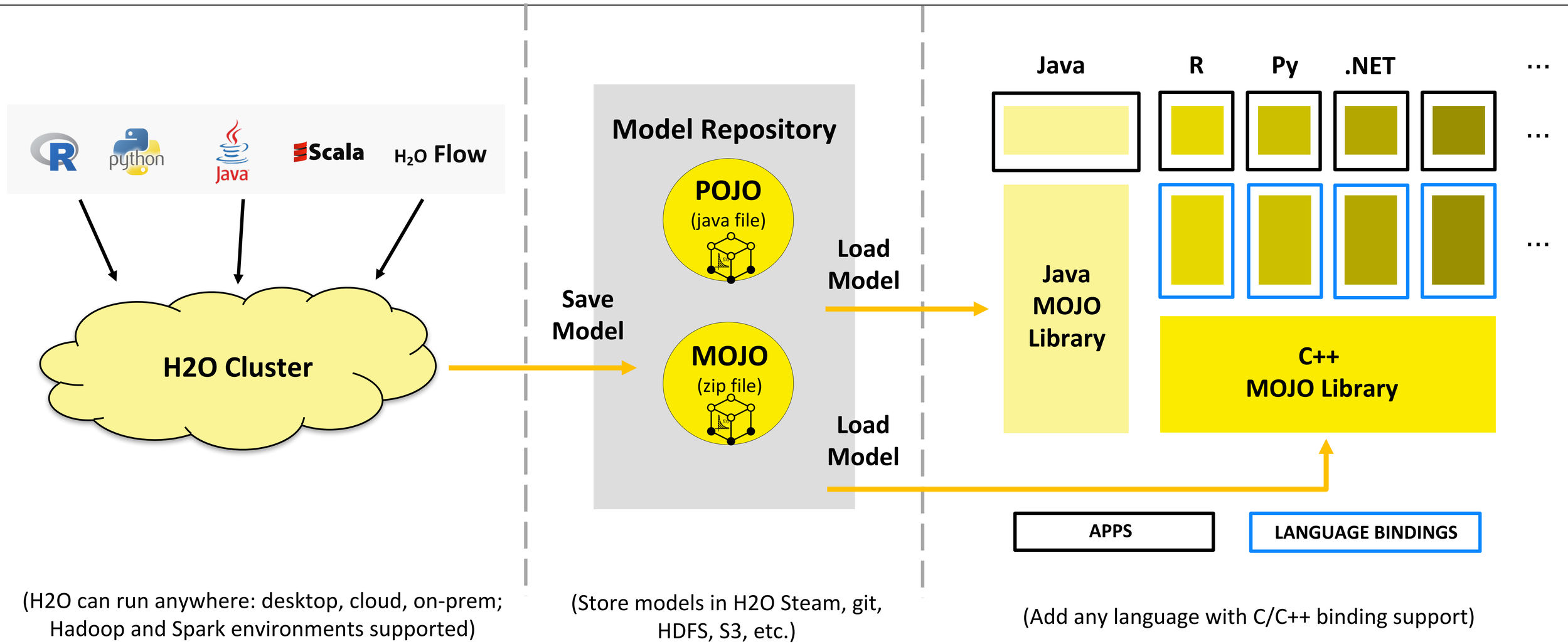
(Store models in H2O Steam, git, HDFS, S3, etc.)

(Add any language with C/C++ binding support)

**Model Training** → **Model Management** → **Model Deployment**

H2O

# MOJOs Enable Machine Learning Model Predictions in Most Languages




(H2O can run anywhere: desktop, cloud, on-prem; Hadoop and Spark environments supported)

(Store models in H2O Steam, git, HDFS, S3, etc.)

(Add any language with C/C++ binding support)

**Model Training** → **Model Management** → **Model Deployment**

H2O

# POJO vs MOJO

| | Java POJO | MOJO / Java Runtime | MOJO / C++ Runtime |
|---|---|---|---|
| **LANGUAGES** | • Java | • Java | • C++, R, Python, .NET, other |
| **ALGORITHMS** | • All | • GLM, DRF, GBM, GLRM (but eventually all) | • GBM (but eventually all) |
| **COMPILING** | • Compiled<br>• Large POJO Compilation Errors | • Interpreted<br>• No compile errors | • Same as Java |
| **CLASS LOADING** | • Java class loading issues for many models — must tune MaxPermSize | • No Java class loading issues (very few fixed number of classes) | • (Does not apply) |
| **ALLOCATION** | • Models use PermGen storage | • Models stored in the Java heap | • Models stored in the C heap |
| **PERFORMANCE** | • Faster for small trees (about 1.5x-2x) | • Faster for large trees (about 20x) | • Same as Java |
| **BACKWARD COMPATIBILITY** | • POJO genmodel backward compatibility unsupported<br>• Difficult to run old and new versions side-by-side (requires multiple library versions and classloading tricks) | • Strong MOJO genmodel backward compatibility<br>• Easy to run old and new versions side-by-side<br>• Same prediction results with future genmodels for a saved MOJO | • Same as Java |
| **SIZE** | • ~10x larger than MOJO, so ~10x larger than .zip file | • Size is 1/10th of a POJO | • Same as Java |
| **EASY WRAPPER** | • Works with Java EasyPredict API | • Works with Java EasyPredict API | • Works with C++ EasyPredict API |
| **DECISION VISIBILITY** | • Decisions are visible in generated code | • Opaque (but open source) binary format<br>• Visualization tools provided (e.g. tree viewer) | • Same as Java |

# C++ MOJO (MOCO) Scoring Demo

In [17]:
```
import unittest
import os
import sys
import h2omojo
```

In [18]:
```
mojo_model = h2omojo.load_mojo_model(mojo_path='/Users/avkashchauhan/learn/customers/mojo-cpp/airl
ine_unzipped')
```

In [19]:
```
def raw(mojo_model):
    row2 = []
    n = mojo_model.nfeatures()
    for i in range(n):
        row2.append(0.0)
    row2[0] = 68
    row2[1] = 2
    row2[2] = 2
    row2[3] = 0
    row2[4] = 6

    pred2 = mojo_model.score0(row2)

    n = mojo_model.get_preds_size()
    if n != len(pred2):
        raise Exception("Size mismatch")

    if True:
        for i in range(len(pred2)):
            print(pred2[i])

        print("")
```

In [21]:
```
h2omojo.set_verbosity(0)
raw(mojo_model)
```

```
1.0
0.522506084464
0.477493915536
```

H2O.ai

# Spark UDF Example

- Here is the Sample Code Snippet

```
import _root_.hex.genmodel.GenModel
import _root_.hex.genmodel.easy.{EasyPredictModelWrapper, RowData}
import _root_.hex.genmodel.easy.prediction
import _root_.hex.genmodel.MojoModel
import _root_.hex.genmodel.easy.RowData

// Load Mojo val mojo = MojoModel.load("/Users/avkashchauhan/learn/customers/mojo_bin/gbm_model.zip")
val easyModel = new EasyPredictModelWrapper(mojo)

// Get Mojo Details
var features = mojo.getNames.toBuffer

// Creating the row
val r = new RowData
r.put("AGE", "68")
r.put("RACE", "2")
r.put("DCAPS", "2")
r.put("VOL", "0")
r.put("GLEASON", "6")

// Performing the Prediction
val prediction = easyModel.predictBinomial(r).classProbabilities
```

- Visit: https://github.com/Avkash/mldl/blob/master/code/scala/spark_udf_score.md

# Hive UDF Example

- Visit github: https://github.com/h2oai/h2o-tutorials/tree/master/tutorials/hive_udf_template
  - Hive POJO UDF
    - https://github.com/h2oai/h2o-tutorials/tree/master/tutorials/hive_udf_template/hive_udf_pojo_template
  - Hive MOJO UDF
    - https://github.com/h2oai/h2o-tutorials/tree/master/tutorials/hive_udf_template/hive_udf_mojo_template
  - Hive Multi MOJO UDF
    - https://github.com/h2oai/h2o-tutorials/tree/master/tutorials/hive_udf_template/hive_multimojo_udf_template

# Hive MOJO UDF Demo

- **Preparation to have test data on Hive**
  - Copying dataset to HDFS
  - Adding test dataset into Hive
- **Your Models**
  - Get your MOJO model (model.zip) and h2o-genmode.jar
- **Working on Repo**
  - Clone the repo
  - Copy the model and genmodel from exported location to into the Hive UDF project
  - Update the pom.xml to Reflect Hadoop and Hive Versions
  - Now Compiling the UDF Jar File
  - Copying the final builds files to HDFS
  - Adding JAR files to Hive
  - Validating the UDF function is in Hive
  - Testing the solution in Hive
- Visit: https://github.com/Avkash/mldl/blob/master/orgs/h2o/hive_udf_prostate.md

# Handling unseen categorical with MOJO/POJO

- Question:
  - **What happens when you try to predict on a categorical level not seen during training?**
- If given data has unseen categorical
  - Unseen categorical levels are turned into NAs,
    - Follow the same behavior as an NA
  - When training data has NO - NA
    - Unseen categorical levels in the test data follow the majority direction
      - » the direction with the most observations
  - When training data has NA
    - Unseen categorical levels in the test data follow the direction that is optimal for the NAs of the training data


avkash@h2o.ai