THE SALAMI METHOD

ADI SHAVIT

*C and C++ are probably the only viable languages for **true** cross-platform development.*

About me

- Software Architect
- Computer Vision, Machine Learning Specialist
- Consultant
- Co-founder
- Core C++ User Group Organizer :: next meetup: Nov 30th
- Blog: videocortex.io

X-PLATFORM

- ASIC
- EMBEDDED
- MOBILE: iOS, ANDROID
- DESKTOP: WINDOWS, LINUX, OSX
- BROWSER: PLUGINS, NaCL, JS, WASM
- CLOUD: SERVERS, DOCKER, Node.js, Serverless
- …AND MORE:
  - VEHICLES, IoT, CPU/GPU

UNFORTUNATELY…

C and C++ are probably the only viable languages for true cross-platform development.

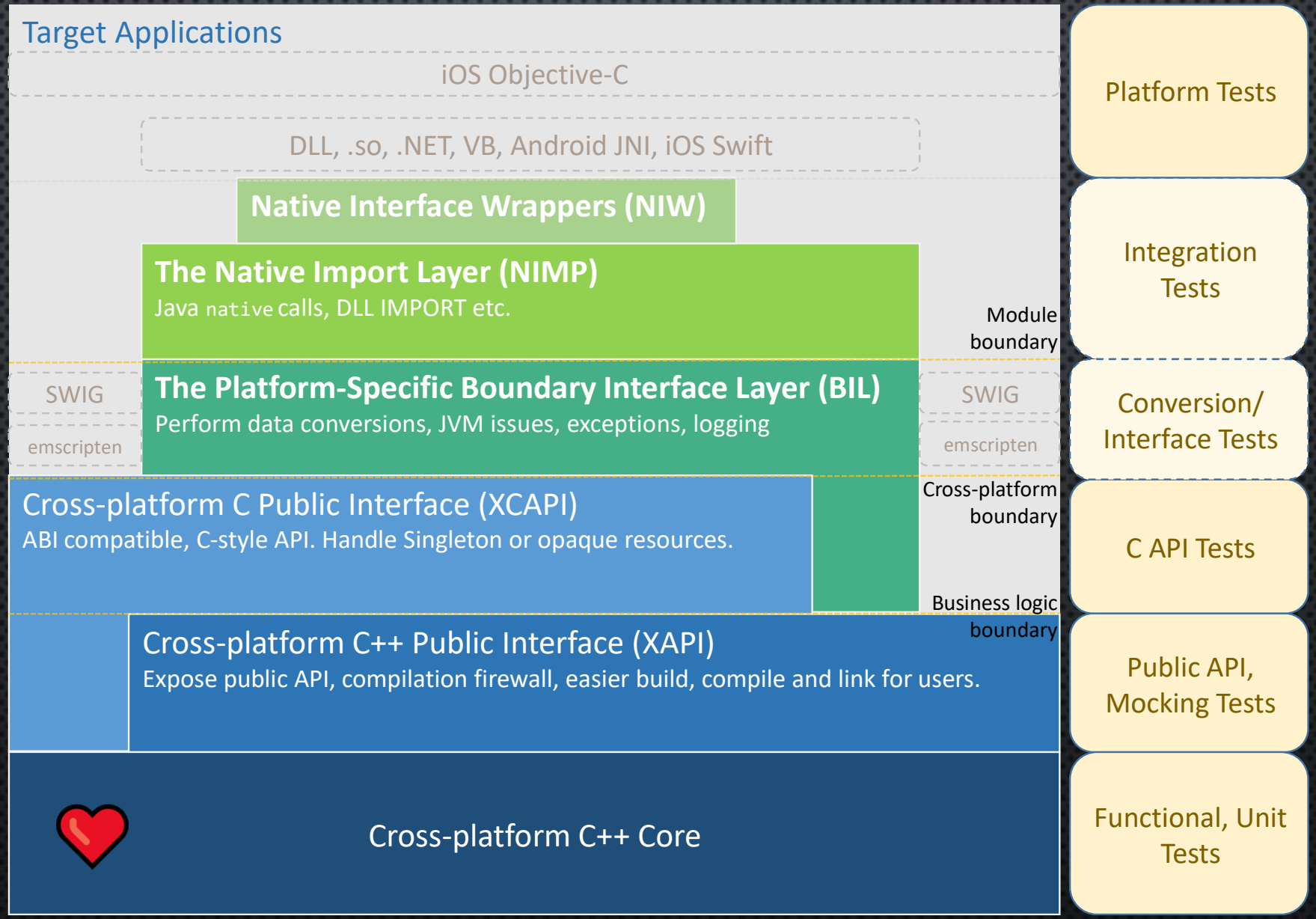
POPULAR PASTIME: CODE PASTA

- REFACTORING AND MAINTENANCE NIGHTMARE
- NON-PORTABLE
- UNTESTABLE
- BUG-PRONE
- MIXING OF SKILLS

- MODULE BOUNDARIES (DLL, SO APIS):
  - ERROR HANDLING
  - EXCEPTIONS: MAYBE TERMINATION OR UNDEFINED-BEHAVIOR

The Salami Method

- Born of Frustration, Blood, Sweat and Tears
- A thin, transparent layer for each aspect
- More easily:
  - Build
  - Test
  - Debug
  - Manage
  - Maintain


Target Applications
iOS Objective-C
DLL, .so, .NET, VB, Android JNI, iOS Swift
Native Interface Wrappers (NIW)
The Native Import Layer (NIMP)
Java native calls, DLL IMPORT etc.
Module boundary
SWIG
emscripten
The Platform-Specific Boundary Interface Layer (BIL)
Perform data conversions, JVM issues, exceptions, logging
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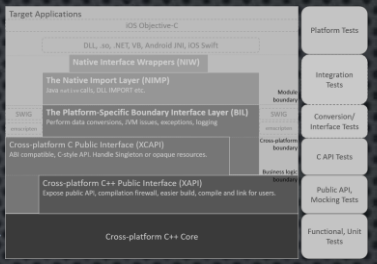
Cross-platform boundary
Cross-platform C Public Interface (XCAPI)
ABI compatible, C-style API. Handle Singleton or opaque resources.
Business logic boundary
Cross-platform C++ Public Interface (XAPI)
Expose public API, compilation firewall, easier build, compile and link for users.
Cross-platform C++ Core
Platform Tests
Integration Tests
Conversion/ Interface Tests
C API Tests
Public API, Mocking Tests
Functional, Unit Tests

SLICING BENEFITS

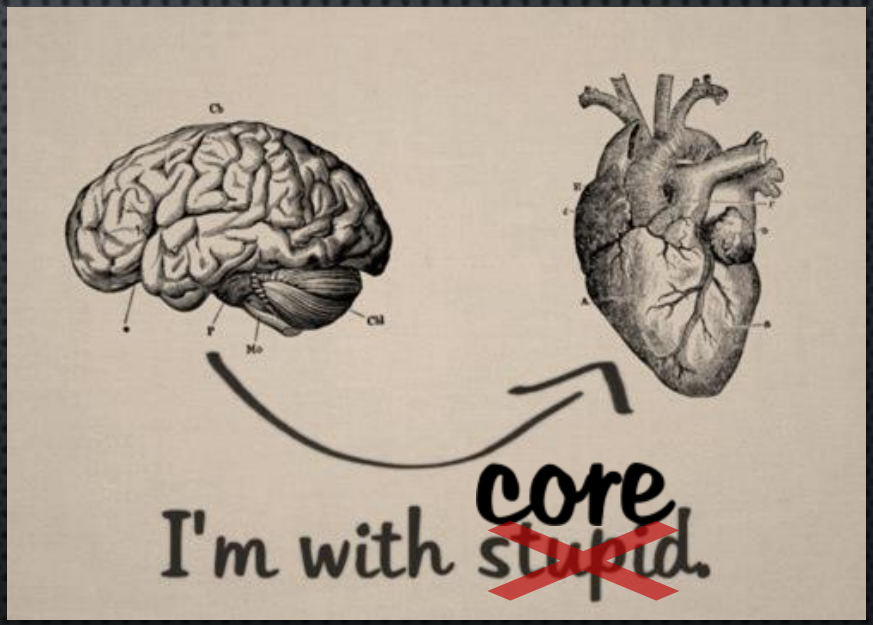
- THE DRY PRINCIPLE: AVOIDS DUPLICATION AND REIMPLEMENTATION
- SINGLE RESPONSIBILITY AND TESTABILITY
- CONSISTENCY : BUSINESS LOGIC IS *ISOLATED* AND *SHARED*
- NEW PLATFORM READY
- DEVELOPER SKILLS
- REFACTORING

Like all good architectures, the Salami Method tries to cleanly separate concerns. Nevertheless, it lacks the greasy, heart-attack-inducing goodness of a good salami.

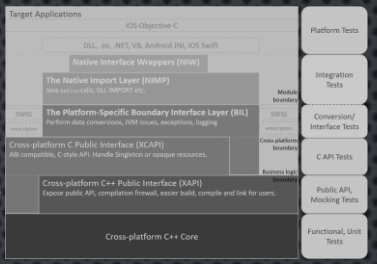
CROSS PLATFORM C++ CORE



- The Core
- The Business Logic
- Proprietary Code, IP
- Idiomatic C++ code
- X-Platform Build
- Static Library
- Testing: Unit, Functional



XAPI: X-PLATFORM PUBLIC C++ INTERFACE

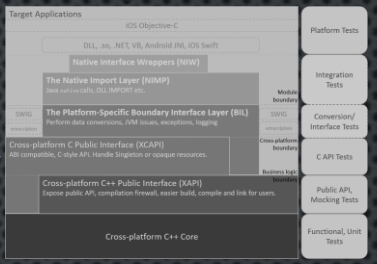


- THE *PUBLIC* C++ CORE API
- APPLY GOOD API DESIGN PRINCIPLES – THINK OF THE SERVICE CONSUMERS
- CONSIDER:
  - INITIALIZATION AND SHUTDOWN; LIFETIME MANAGEMENT; SESSIONS; CONFIGURATION; SERIALIZATION ETC.
- HIDES PROPRIETARY CODE/DEPENDENCIES, REDUCE DEPENDENCIES, PIMPL IDIOM
- C++ MODULES EXPORT POSTERCHILD (C++20)
- TESTING: MOCK AND UNIT TEST THE API
- NAMING CONVENTION:
  - WITH CORE FILE: `core.cpp` → CORRESPONDING: `core_api.cpp`
- MAY SKIP FOR SMALL PROJECTS

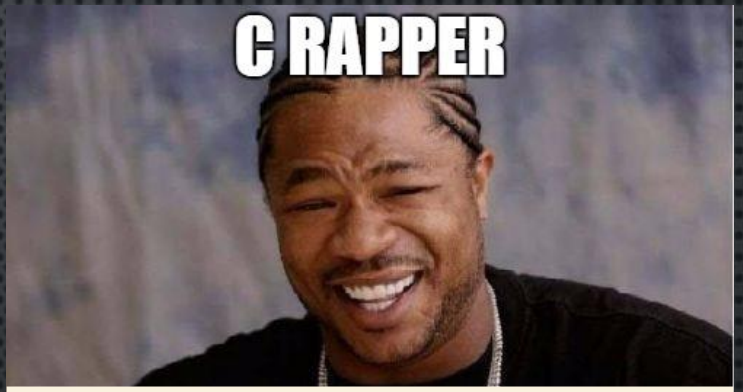
WARNING

WARNING

XCAPI: THE X-PLATFORM PUBLIC C INTERFACE



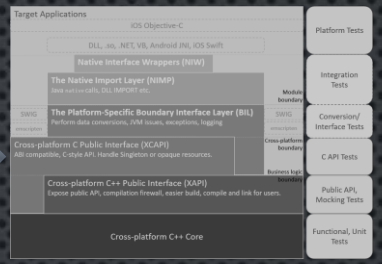
- THE TRUE *LINGUA-FRANCA* OF COMPUTING IS C: SIMPLE ABI
- A *THIN* C API *WRAPPER* OVER XAPI:
  - `extern "C"` FOR LINKING ABI
  - PORTABLE TYPE CONVERSIONS: E.G. `std::string` → `char*`
  - C++ OBJECT LIFETIME MANAGEMENT VIA C INTERFACE:
    - GLOBAL / SINGLETON
    - OPAQUE HANDLES
  - OVERLOADED C++ FUNCTIONS → MULTIPLE C FUNCTIONS
- TESTING: MOCK AND UNIT TEST THE C API/SDK
- NAMING CONVENTION:
  - WITH XAPI FILE: `core_api.h` → CORRESPONDING: `core_c_api.cpp`



YO DAWG

In wrapper *implementation*, use type helpers like `gsl::span` or `std::string_view` to *lift* weaker low-level C types to stronger, safer types as early as possible!

XCAPI

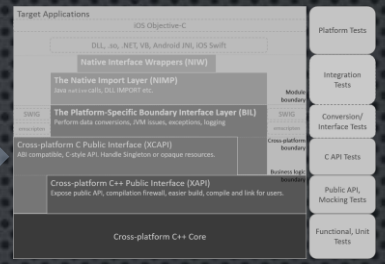



```
// foo_session_c_api.h
extern "C"
{
   bool initFromFileName(std::string const& fileName);
   bool initFromCount(int count);
   bool processBuffer(uint8_t* buffer, int size);
   bool isReady();
}
```

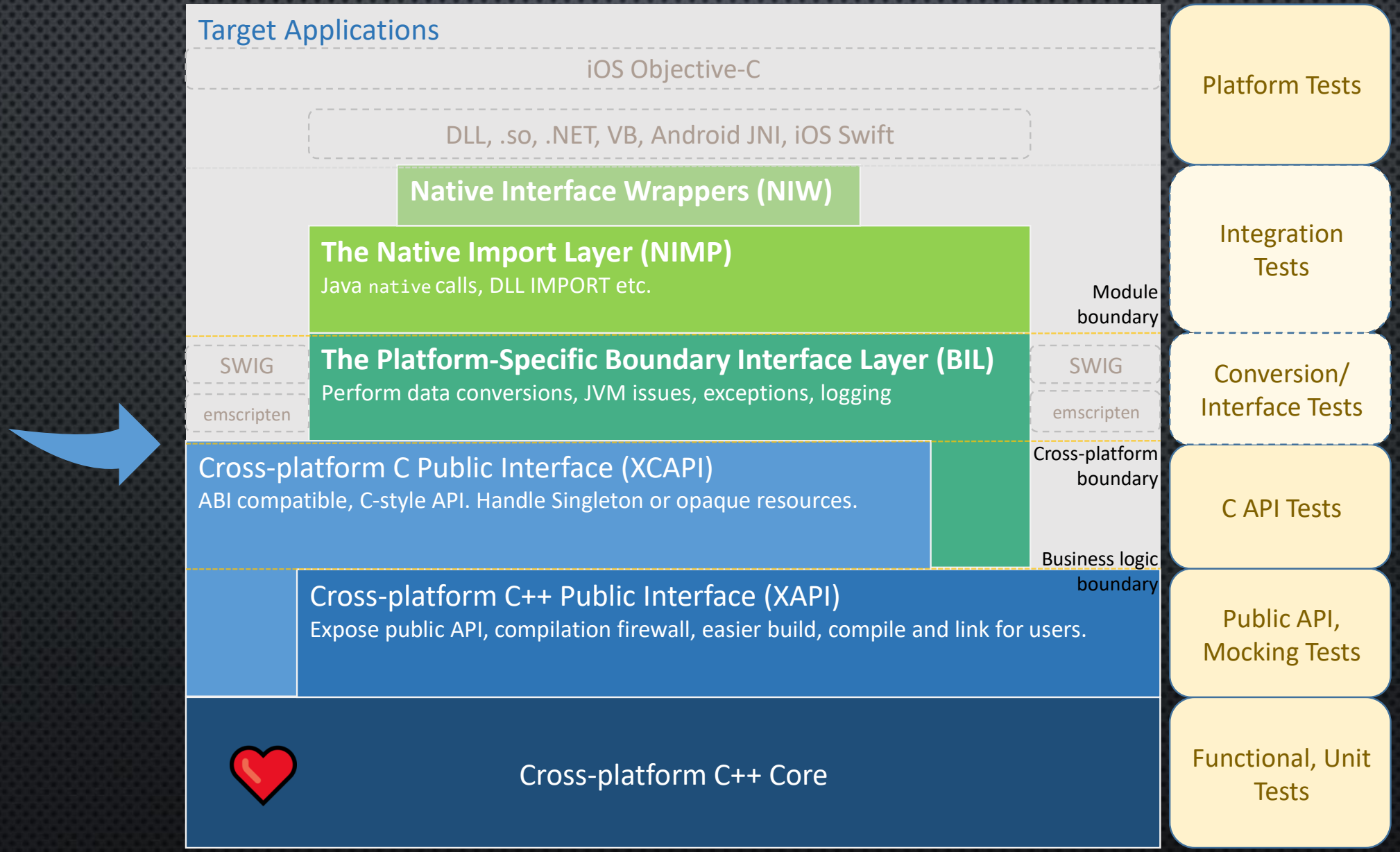
"C" will sometimes mean a C-*like* function interface

(i.e. not necessarily pure C)

XCAPI




```cpp
// foo_session_c_api.cpp
#include <foo_session_api.hpp> // C++ API
#include "foo_session_c_api.h" // header for this file

Foo::Session the_session; // use a single global "singleton".

bool initFromFileName(std::string const& fileName)
{  return the_session.init(fileName); }

bool initFromCount(int count)
{  return the_session.init(count); }

bool processBuffer(uint8_t* buffer, int size)
{  return the_session.process(gsl::span<uint8_t>(buffer, buffer+size)); }
// Use gsl::span<> -----------^^^^^^^^^^^^^^^^^^

bool isReady()
{  return the_session.isReady() }
```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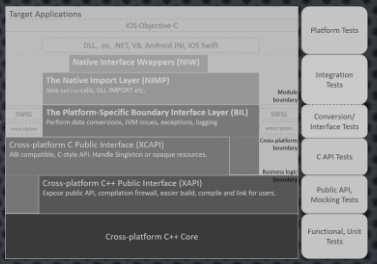
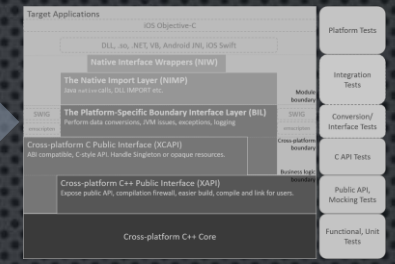
BIL: Platform Boundary Interface Layer



- Platform Specific Code!
- Implemented per Target platform:
  - Conversions: Types and Values
  - Constraints
  - Conventions
  - Set up platform-specific logging logic
- Module Boundary: DLL, .so
  - No exceptions can escape!
- Testing: ? LMK!
- Naming Convention:

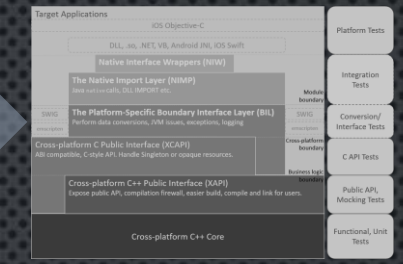
  XCAPI file: `core_c_api.h` → `core_c_api_dll.cpp`, `core_c_api_jni.cpp`

BIL – DLL/SO EXAMPLE



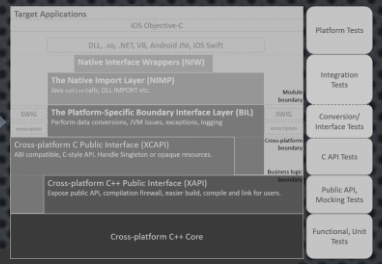

```
// foo_session_c_api_dll.h
extern "C"
{
   bool DLL_EXPORT FooSession_initFromFileName(LPCSTR fileName);
   bool DLL_EXPORT FooSession_initFromCount(int count);
   bool DLL_EXPORT FooSession_processBuffer(unsigned char* buffer, int size);
   bool DLL_EXPORT FooSession_isReady();
}
```

BIL – DLL EXAMPLE



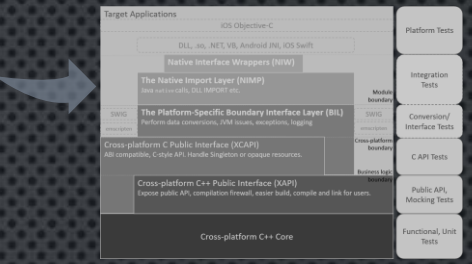

```
// foo_session_c_api_dll.cpp
#include <foo_session_c_api.h>     // C API
#include "foo_session_c_api_dll.h" // header for this file

bool DLL_EXPORT FooSession_initFromFileName(LPCSTR fileName) try
{  return ::initFromFileName(fileName); } // automatic LPCSTR conversion to std::string
catch (...) { return false; }

bool DLL_EXPORT FooSession_initFromCount(int count) try
{  return ::initFromCount(count); }
catch (...) { return false; }

>bool DLL_EXPORT FooSession_processBuffer(uint8_t* buffer, int size) try
{  return ::processBuffer(buffer, size); }
catch (...) { return false; }

bool DLL_EXPORT FooSession_isReady() try
{  return ::isReady() }
catch (...) { return false; }
```

BIL – ANDROID JNI EXAMPLE




```
#include <jni.h>                 // JNI headers
#include <android/log.h>         // Android logging facilities
#include <foo_session_c_api.h> // C API
#include "jni_utils.h"           // For JNIByteArrayAdapter and exceptionHandler

JNIEXPORT jboolean JNICALL Java_initFromFileName(JNIEnv* env, jobject thiz, jstring fileName) try
{  return ::initFromFileName(jni_utils::getString(env, fileName)); } // JNI string helper
catch(...) { return exceptionHandler(); }

JNIEXPORT jboolean JNICALL Java_initFromCount(JNIEnv* env, jobject thiz, jint count) try
{  return ::initFromCount(count); }
catch(...) { return exceptionHandler(); }

JNIEXPORT jboolean JNICALL Java_processBuffer(JNIEnv* env, jobject thiz, jbyteArray buffer) try
{
   jni_utils::JNIByteArrayAdapter buffer_span(env, buffer); // JNI helper wrapper
   return ::processBuffer(buffer_span.ptr(), buffer_span.size());
}
catch(...) { return exceptionHandler(); }

JNIEXPORT jboolean JNICALL Java_isReady(JNIEnv* env, jobject thiz) try
{  return ::isReady() }
catch(...) { return exceptionHandler(); }
```

NIMP: Native Import Layer

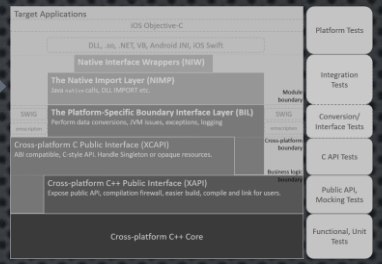


- On Target Platform:
  - Device, HW, OS, Language
- Uses "*Native-Native*" Interface
  - Reflects BIL
  - Usually low level

- Testing: Target Integration Tests
- Naming Convention:

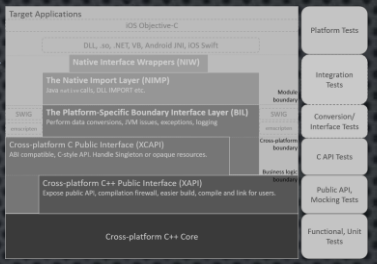
`core_native.java`, `core_native_dll_wrapper.cs` , `core_native.js`

NIMP




```
// foo_session_native.java
// imports ...
public class FooSession
{
   static { System.loadLibrary("native_foosession"); } // load the DLL

   public static native boolean initFromFileName(String fileName);
   public static native boolean initFromCount(int count);
   public static native boolean processBuffer(byte[] buffer);
   public static native boolean isReady();
}
```

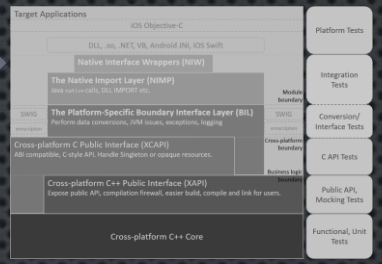
NIW: INTERFACE WRAPPERS



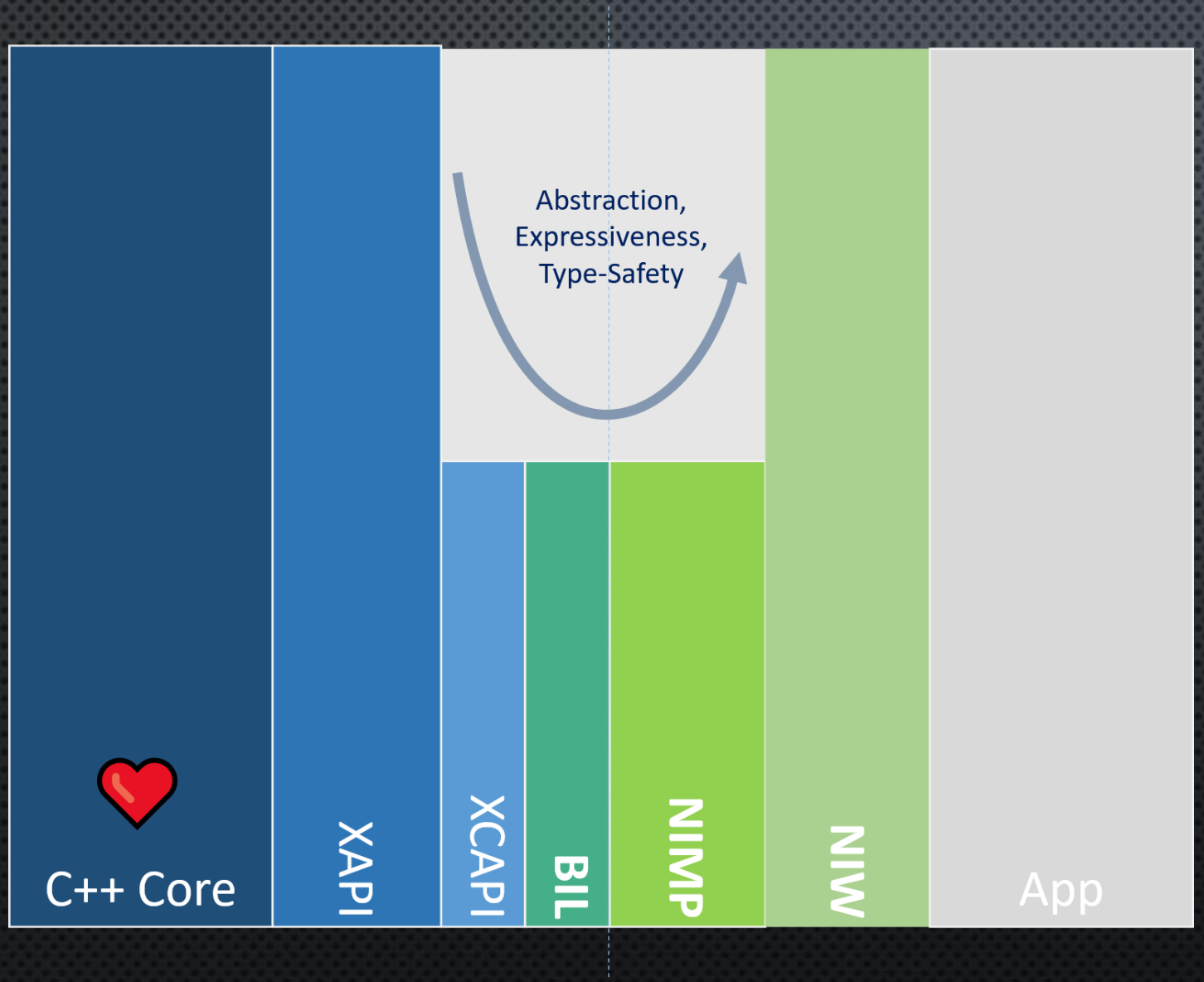
- High Level NIMP Wrappers
- More natural, familiar syntax
- Higher level types
  - Device, HW, OS, Language

- Testing: Target Integration Tests
- Naming Convention: depends on target and context

NIW




```java
// face_detector_native.java
import android.graphics.PointF; // Android point type

public class FaceDetector
{
   static { System.loadLibrary("native_facedetector"); } // load the DLL

   // native import function/method, returns a float array
   public static native float[] getFaceCenterPoint();

   // Java-ized wrapper: return proper 2D point type
   public static PointF GetFaceCenterPoint()
   {
      float[] centerPt = getFaceCenterPoint();     // call native function
      return new PointF(centerPt[0], centerPt[1]); // return as Android Java type: PointF
   }
}
```



BEAUTIFUL SYMMETRY

QUICK EXAMPLE

(time allowing)

github.com/adishavit/party_parrot

XAPI / XCAPI color_cycle.h

```
namespace color_cycle
{
  void rotate_hue(cv::Mat3b const& img, cv::Mat3b& result_img, int hsteps);
  void clear_all();
}
```

BIL color_cycle_js.cpp

```cpp
#include <emscripten.h>
cv::Mat3b bgr_g, bgr_out_g; // global data
extern "C"
{
   bool EMSCRIPTEN_KEEPALIVE rotate_colors(int width, int height, cv::Vec4b* frame4b_ptr, cv::Vec4b* frame4b_ptr_out,
                                           int hsteps) try
   {
      cv::Mat4b rgba_in(height, width, frame4b_ptr);      // wrap memory pointers with proper
      cv::Mat4b rgba_out(height, width, frame4b_ptr_out); // cv::Mat images (no copies)

      bgr_g.create(rgba_in.size());                       // allocate 3-channel images if needed
      bgr_out_g.create(rgba_in.size());

      cv::cvtColor(rgba_in, bgr_g, CV_RGBA2BGR);          // rearrange channels and drop alpha channel

      color_cycle::rotate_hue(bgr_g, bgr_out_g, hsteps); // do the actual work!!

      // mix BGR + A (from input) => RGBA output
      const Mat in_mats[] = { bgr_out_g, rgba_in };
      constexpr int from_to[] = { 0,2, 1,1, 2,0, 6,3 };
      mixChannels(in_mats, std::size(in_mats), &rgba_out, 1, from_to, std::size(from_to)/2);
      return true;
   }
   catch (std::exception const& e) // ...
```

NIMP color_cycle.js

```
// Compute and display the next frame
fp.renderFrame = function () {
  // Acquire a video frame from the video element
  fp.ctx.drawImage(fp.video, 0, 0, fp.video.videoWidth,
                fp.video.videoHeight, 0, 0, fp.width, fp.height);
  var img_data = fp.ctx.getImageData(0, 0, fp.width, fp.height);

  // allocate Emscripten Heap memory buffer only when needed:
  if (!fp.frame_bytes) {
     fp.frame_bytes = _arrayToHeap(img_data.data);
  }
  else if (fp.frame_bytes.length !== img_data.data.length) {
     _freeArray(fp.frame_bytes); // free heap memory
     fp.frame_bytes = _arrayToHeap(img_data.data);
  }
  else {
     fp.frame_bytes.set(img_data.data);
  }

  // Perform operation on copy, no additional conversions needed, direct pointer manipulation
  // results will be put directly into the output param.
  Module._rotate_colors(img_data.width, img_data.height,
                        fp.frame_bytes.byteOffset, fp.frame_bytes.byteOffset,
                        fp.color_change_speed);

  // copy output to ImageData
  img_data.data.set(fp.frame_bytes);
  // Render to viewport
  fp.viewport.putImageData(img_data, 0, 0);
};
```

```
// Given a JS TypedArray, Module._malloc() a buffer of the same size
function _arrayToHeap(typedArray) {
  var numBytes = typedArray.length * typedArray.BYTES_PER_ELEMENT;
  var ptr = Module._malloc(numBytes);
  heapBytes = Module.HEAPU8.subarray(ptr, ptr + numBytes);
  heapBytes.set(typedArray);
  return heapBytes;
}

// Free the malloced data. No GC works on this heap.
// Alas, no dtors in JS either :-(
function _freeArray(heapBytes) {
  Module._free(heapBytes.byteOffset);
}
```

THE HOST APP index.html

```
<div id="video_place"></div>
<script src='color_cycle_asm.js'></script>
<script src='color_cycle.js'></script>
<script>
    var fp = makeFrameProcessor("sirocco.mp4");
    function updateColorChangeSpeed(newValue) { fp.color_change_speed = newValue; }
</script>
<input type="range" min="0" max="20" value="1"
oninput="updateColorChangeSpeed(this.value)"
onchange="updateColorChangeSpeed(this.value)"/>
```

Video Cortex

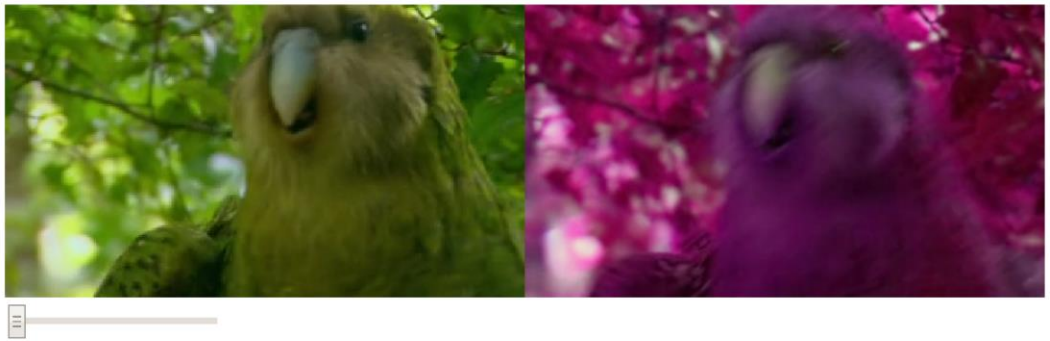
Insights and Visions

Blog

A now, without further ado…

The Party Parrot App

And here's the app in all its glory (I literally pasted the code above into the post's Markdown):



On the left, the original, a regular HTML5 video.
On the right, the same video being processed live, frame-by-frame cycling of the frame's hue channel.
This is a live, real time view, running in the browser!

Use the slider to change the color cycling speed.

http://videocortex.io/2017/opencv-web-app

videocortex.io @AdiShavit