Automated Run-Time Validation for Cryptographic Modules

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Traditional Conformance Testing

Vendor	CST Lab	CMVP NIST and CSEC	User
Designs and Produces Hardware • Software • Firmware	***Tests for Conformance*** Derived Test Requirements	***Validates***	***Specifies and Purchases***
Define Boundary **Define Approved Mode of Operation** **Security Policy**	**CAVP Algorithm Testing** **Documentation Review** **Source Code Review** **Operational and Physical Testing**	**Review Test Results** **Ongoing NVLAP Assessment** **Issue Certificates** **NIST Cost Recovery Fee**	**Security and Assurance** **Applications or products with embedded modules**

A look at the challenges today: key facts in the Verizon 2016 Breach Investigation Report

1. **Most attacks exploited known vulnerabilities where a patch has been available for months, often years**
   - The top 10 vulnerabilities [Common Vulnerabilities and Exposures, or CVEs] accounted for 85% of successful exploit traffic.
2. **Main reason**
   - 58% of businesses don't have "mature" patch management processes.
3. **No one is immune**
   - Attackers are getting better
   - In 93% of cases, it took attackers minutes or less to compromise systems.
4. **Most breaches are about money**
   - Any cyber asset you have that can be monetized makes you a target.
   - Cyber-espionage targets IP in manufacturing [47% of breaches] and IT.

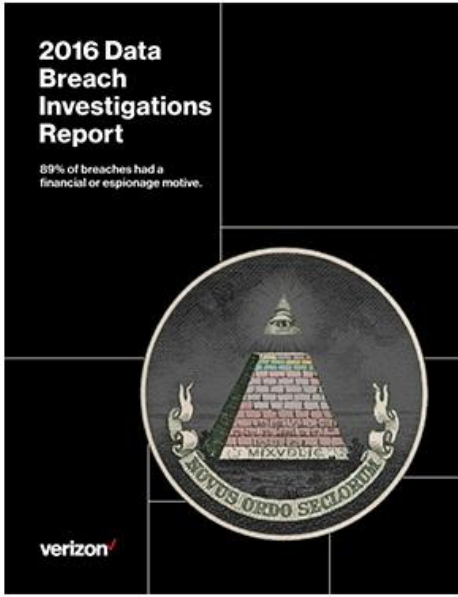


Image Courtesy: verizonenterprise.com/verizon-insights-lab/dbir/2016/

Limitations of Traditional Conformance Testing

1. **Long Validation Cycles**
   - Well beyond product development cycles
   - Hinder adoption of new technology by the Federal Government
2. **Shallow Depth of Testing**
   - Software testing methodology inadequate for today's complexity of crypto implementations
   - Hardware testing lags state-of-the-art
3. **Costly and Rigid**
   - Difficult to obtain compliance assurance on platforms of actual use
   - Limits the industry's efforts to validate more products
   - Prevents the industry from fixing critical problems, e.g. CVE, without breaking program rules
4. **Impossible to fix within the existing box**
   - Some improvements help but fall short of solving the problems

Image Courtesy: Web

Government-Industry Working Group

1. **Announced last year**
   - Cybersecurity Innovation Forum, September 2015, Washington DC
   - ICMC15, November 2015, Rockville MD
2. **Initiated in December 2015**
   - Founding face-to-face meeting at NIST
3. **Goals**

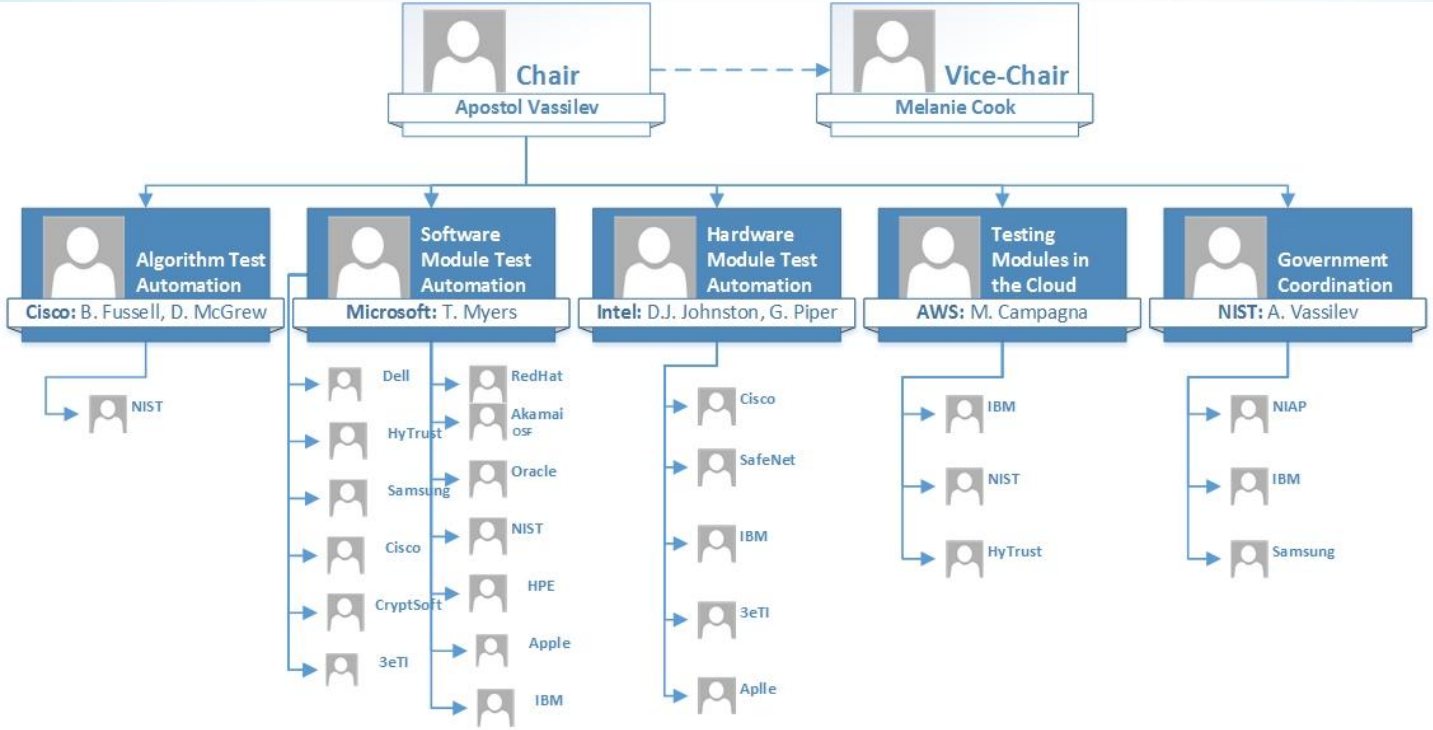
A. Provide powerful economic incentives to the industry
   - Reduce the length and cost of validations
   - Enable Just-In-Time validations through verifiable test artifacts

B. Widen agencies' access to latest technologies
   - maintaining FISMA compliance with up-to-date patches

C. Align with other government test programs
   - Enable Common Criteria to consume FIPS 140 validations not just CAVP

Image Courtesy Monty Python, 1970

Government-Industry Working Group Structure



Working Group Status

1. **Scoping work**
   - Finalizing charter documents for each work area
   - Analysis of FIPS 140 DTR's applicable to work areas
2. **First milestone reached**
   - Automated Cryptography Validation Protocol - ACVP
   - Automated Algorithm Validation System
   - Test and validation automation demo

Image Courtesy: Web

Automated Cryptography Validation Protocol

Considerations

- An automated approach is needed for scalability

Automation

- On premise or via a validation authority
- Customers can test deployed equipment

Remote Validation

- Phased delivery
- Version control to support new requirements and backward compatibility

Extensibility

- Automated revalidation eliminates tension between patches and validation

Reduce Tension

- Validation Authority (NIST)
- Expedite revalidation

3rd Party Verification

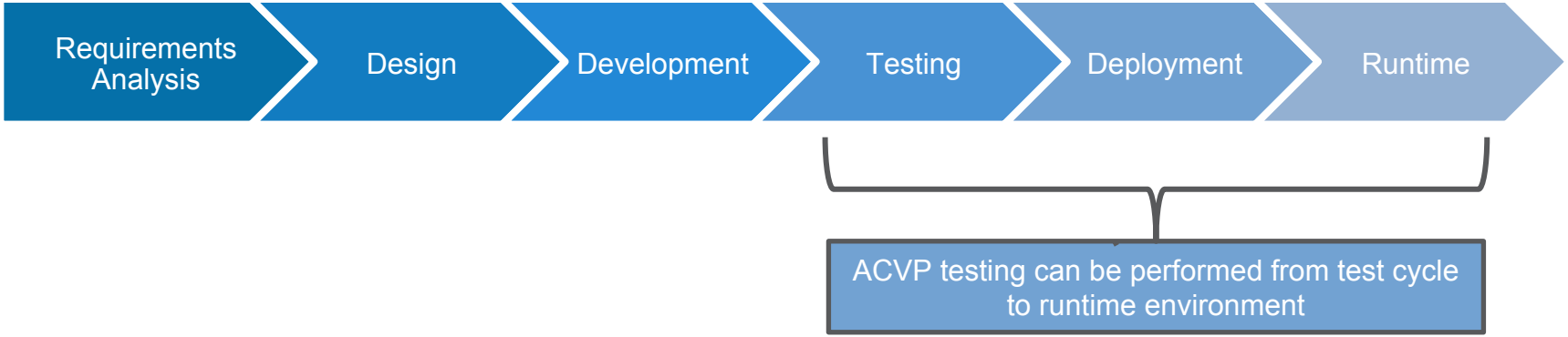
- Mitigate threats as late in the software life cycle as possible
- Help address Insider Threats

Software Lifecycle

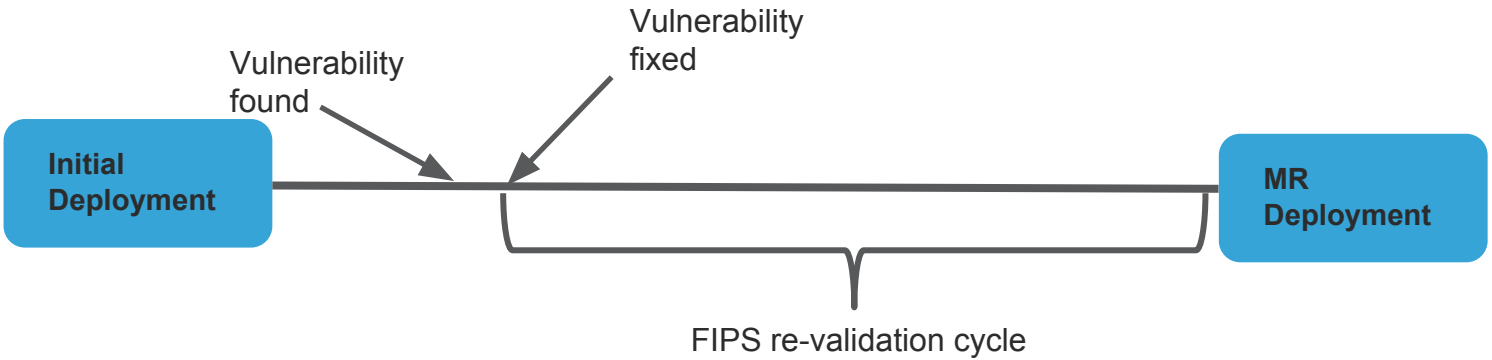
- Simple Protocol can work with any crypto implementation that has access to HTTP

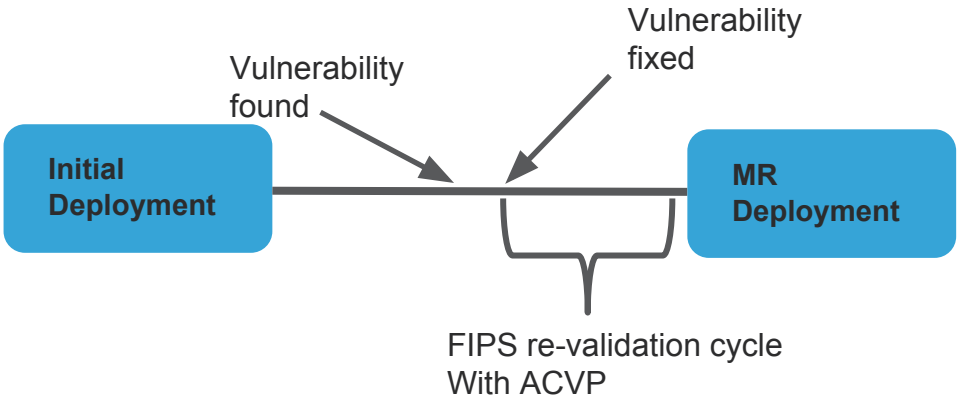
Product Coverage

Software Development Life Cycle



Software Maintenance Life Cycle





ACV Protocol

“Lightweight standards track protocol built on top of existing standard protocols and encoding.”

- TLS 1.2 (optional)
- HTTP(S)
- Java Script Object Notation(JSON)
- JSON Web Token(JWT) Authorization
- Protocol does not define authentication method

ACVP Architecture

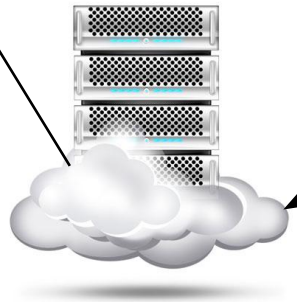
Proxy/Validation Authority Architecture

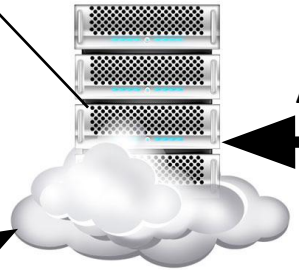
Automated Cryptographic Validation System

ACV Client:
- Integrated into Device under test
- May convert JSON test vectors to format acceptable by crypto module under test
- Returns KAT answers to ACV server in JSON format

ACV Proxy/Server:
- Web hosted service
- Interacts with NIST ACV Server to obtain JSON KAT data
- Optionally generates JSON test vectors
- Optionally performs results verification
- Reports JSON KAT results to NIST ACV Server

Validation Authority Server:
- Web hosted service w/ REST API
- Registers ACV Servers
- Generates JSON KAT vectors
- Validates JSON KAT results
- Publishes validation results from trusted vendor ACV Servers



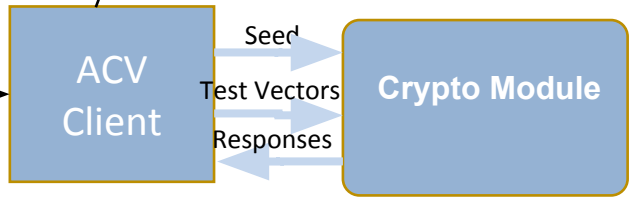


ACV Protocol

ACV

Vendor ACV Server

NIST ACV Server



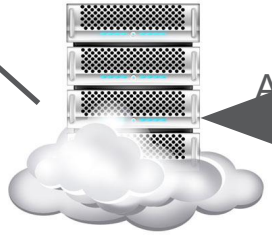
Device Under Test

Base Architecture

Automated Cryptography Validation Protocol

ACV Client:
- Integrated into Device under test
- May convert JSON test vectors to format acceptable by crypto module under test
- Returns KAT answers to ACV server in JSON format

ACV Server:
- Web hosted service
- Generates JSON test vectors
- Performs results verification



ACV Protocol

ACV Server

Entropy Source

ACV Client

Seed

Test Vectors

Responses

DRBG

Encryption

Authentication

Public Key Generation

Key Establishment

Signatures

Crypto Module

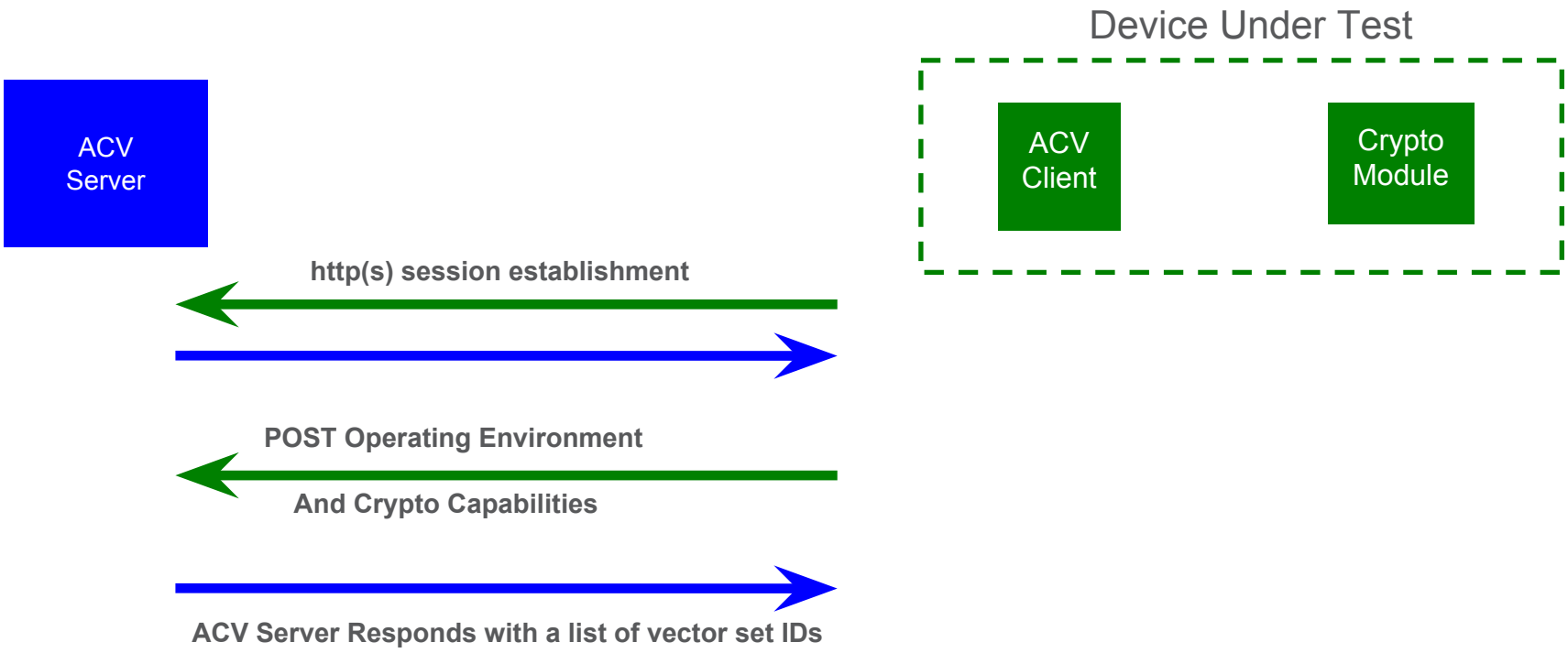
Device Under Test

ACV Protocol:
- Standards-based protocol
- Developed in partnership w/ CMVP
- Extensible to mitigate additional vectors over time
- Open Source to enable independent verification

ACVP Flows

1. Client Registration and Vector Set Creation
2. Client GET of Vector Sets
3. Client POST of Known Answer Test Results
4. Client uses GET method to retrieve results

ACVP Flows – Client Registration and Vector Set Creation



Example: Client registration json body


```
{
    "operation": "register",
    "acv_version": "0.2",
    "oe_information": {
        "vendor_name": "Cisco", "vendor_url": "www.cisco.com",
        "contact": "John Doe", "contact_email": "johndoe@cisco.com",
        "module_name": "Cisco ACV Test Module 1.0",
        "module_type": "Software",
        "operational_environment": {
            "module_version": "1.0",
            "processor": "Intel Woodcrest",
            "operating_system": "Linux 3.1"
        },
```

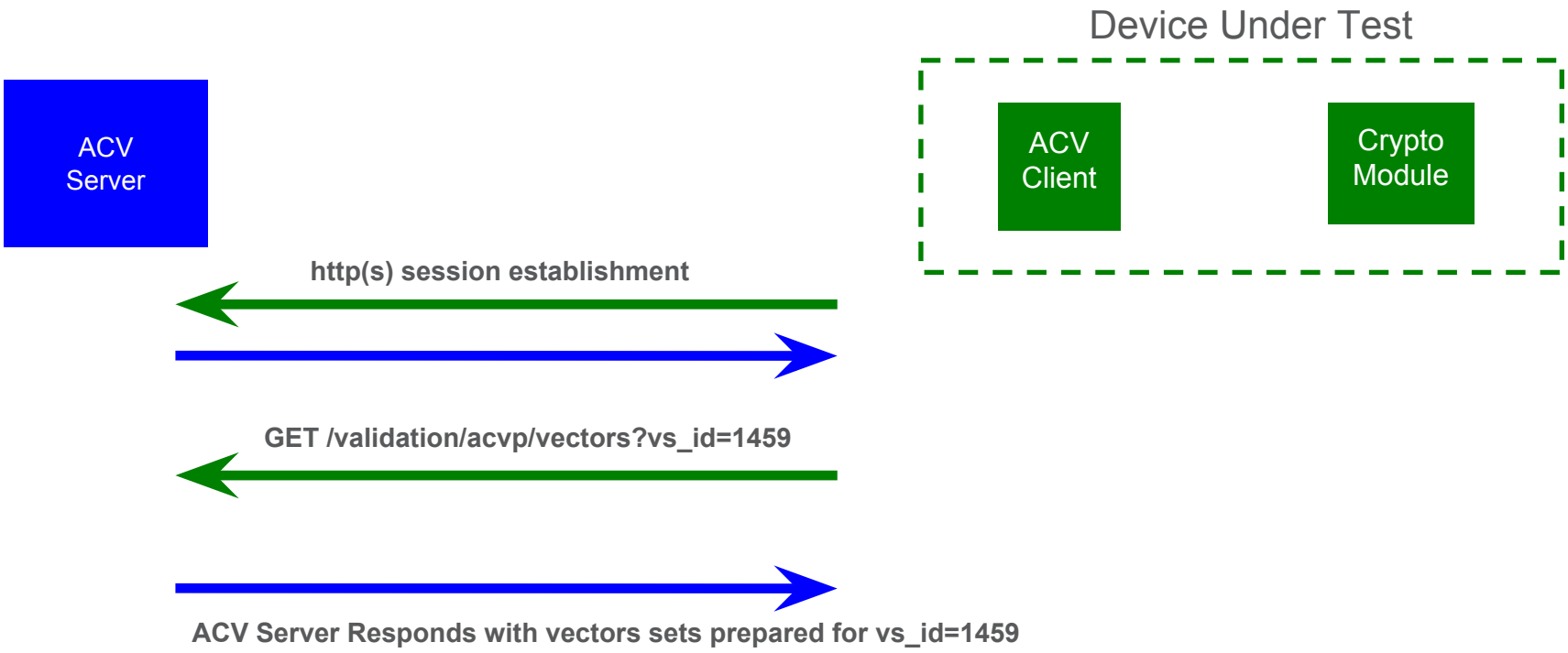
Example: Client registration json body


```
"implementation_description": "Sample crypto module for
    demonstrating ACV protocol."
  },
"capability_exchange": {
"algorithms": [
        { "algorithm": "AES-GCM",
          "mode": "both", "iv_gen": "internal", "iv_gen_mode": "8.2.1",
          "key_lens": [ 128, 256], "tag_lens": [ 96], "iv_lens": [ 96],
           "pt_lens": [ 0, 128, 136 ], "aad_lens": [ 128, 136 ]
  },
```

Example: Server registration response


```
{ "acv_version" : 0.2 ,
  "capability_response" :
    { "vector_sets" : [{"vs_id":1457},{"vs_id":1458}]
    } ,
  "test_session" : {"test_id":474} ,
  "access_token" : "eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.
      eyJpc3MiOiAibmlzdC5vcmciLCJleHAiOiAxNDYzMDc4NTI4LCJjb21wYW5
      5IjogIkNpc2NvIiwianRpIjo0NzR9.6AggT4h10YGrNiTlZrf-
      I7jend5ut6V9Ai_or_LohJE”
 }
```

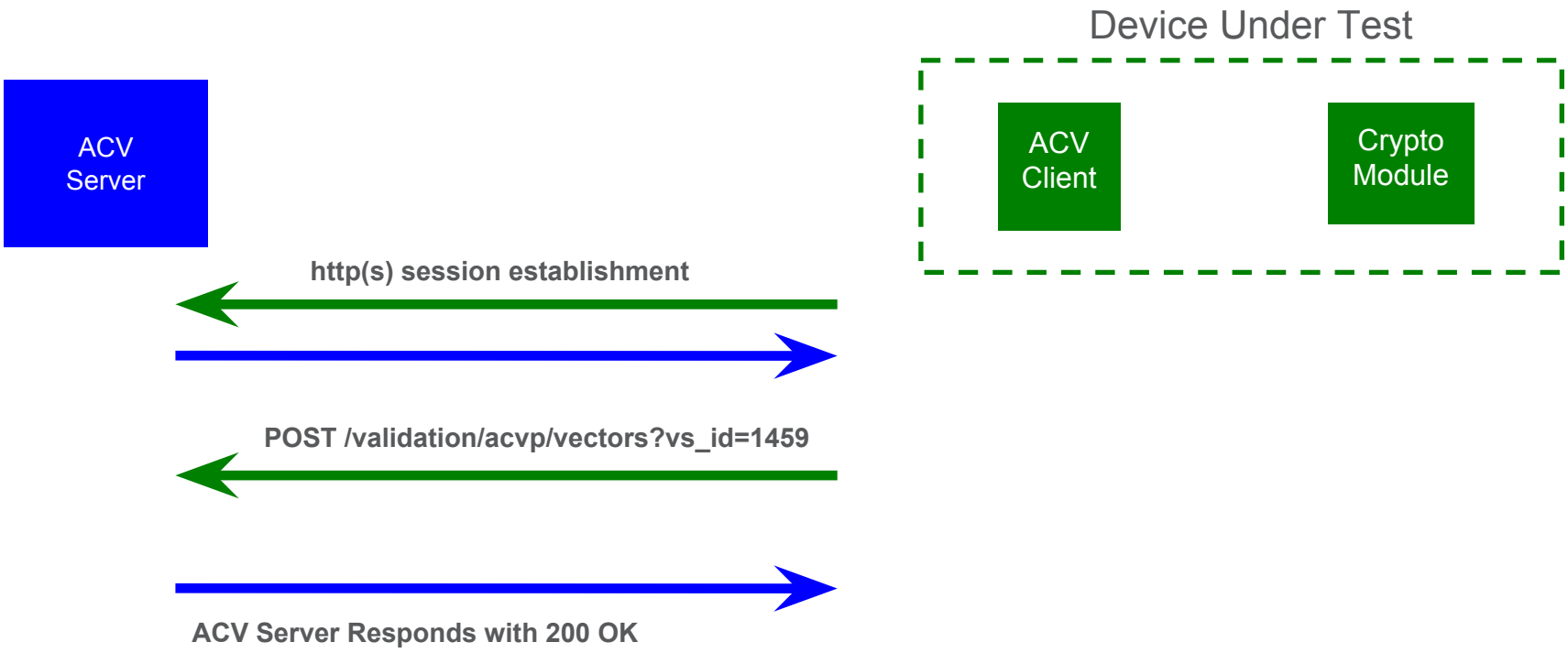
ACVP Flows – Client GET of Vector Sets



Example: Partial vector set in json format


```
{ "acv_version": "0.2”, "vs_id": 1459, "algorithm": "AES-GCM",
  "mode": "encrypt",
  "test_groups": [
    { "keylen": 128, "ivlen": 96, "ptlen": 0, "aadlen": 128, "taglen": 128,
      "tests": [
        { "tc_id": 23400,
          "key": "F3EE815AD9AD595BE7BBE574B25D6313”,  "pt": "",
          "aad": "A01834F0C26F092BADEB6A49A5D598E8” },
        { "tc_id": 23401,
          "key": "0498D606AF65E38915721512514778 2C”,
```

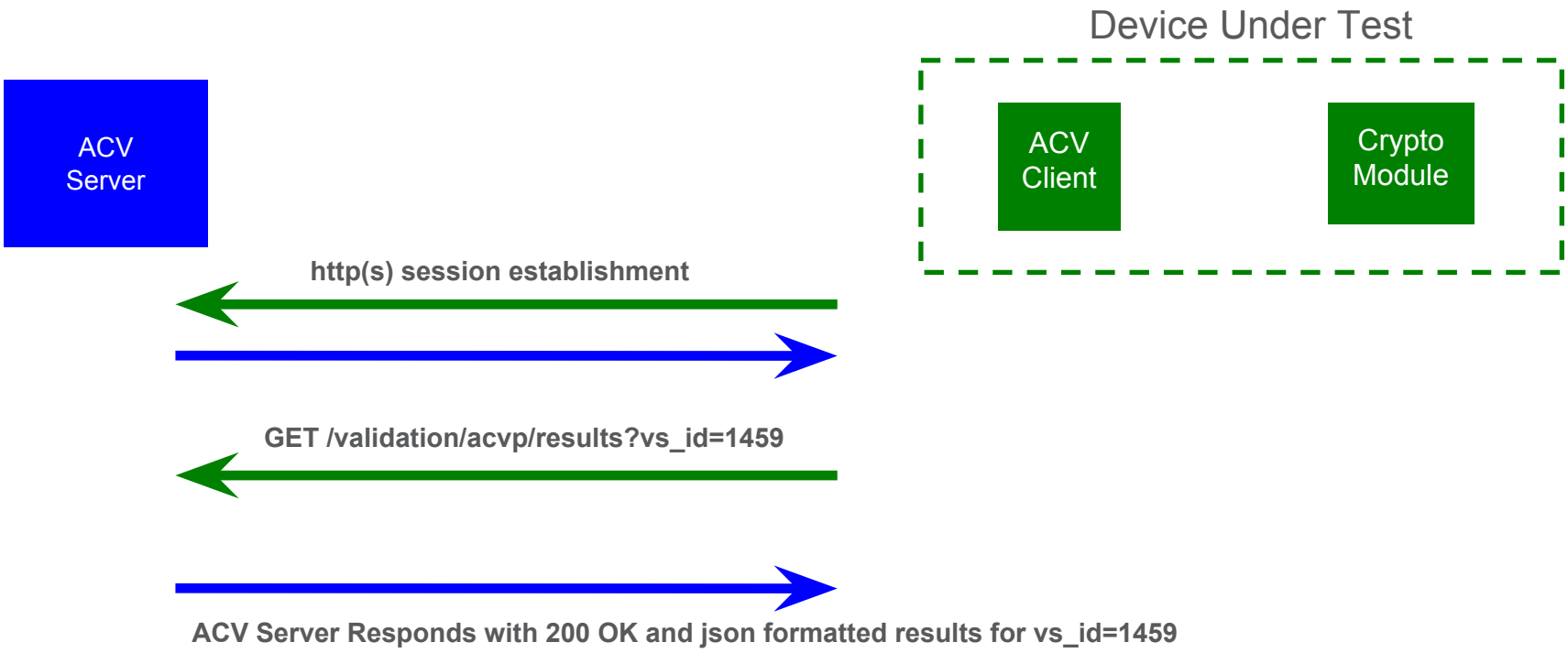
ACVP Flows – Client POST of Known Answer Test Results



Example: Partial vector set response in json format


```
{  "acv_version": "0.2",
   "vs_id": 1459,
   "algorithm": "AES-GCM",
   "mode": "encrypt",
   "test_results": [
      {
         "tc_id": 23400,
         "iv": "01020304A685AE2E7E17642B",
         "ct": "",
         "tag": "D0550D9C53F676C027B998B3C5E5C3C2"
      },
```

ACVP Flows – Client uses GET method to retrieve results



Example: Results returned in json format

HTTP/1.1 200 OK

Content-Type: application/json; charset=utf-8

Date: Thu, 18 May 2016 20:01:26 GMT


```
{"acv_version": "0.2",
 "results" : {
    "disposition" : ”passed",
    "1462" : ”passed" }
 }
```

Demo

Q & A

Example: Decode of Access Token


```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9
.eyJpc3MiOiAibmlzdC5vcmciLCJleHAiOiA
xNDYzMDc4NTI4LCJjb21wYW55IjogIkNpc2N
vIiwianRpIjo0NzR9.6AggT4h10YGrNiTlZr
f-
I7jend5ut6V9Ai_or_LohJEeyJhbGciOiJIU
zI1NiIsInR5cCI6IkpXVCJ9.eyJzdWIiOiIx
MjM0NTY3ODkwIiwibmFtZSI6IkpvaG4gRG9l
IiwiYWRtaW4iOnRydWV9.TJVA95OrM7E2cBa
b30RMHrHDcEfxjoYZgeFONFh7HgQ
```


HEADER: ALGORITHM & TOKEN TYPE


```
{
  "alg": "HS256",
  "typ": "JWT"
}
```


PAYLOAD: DATA


```
{
  "iss": "nist.org",
  "exp": 1463078528,
  "company": "Cisco",
  "jti": 474
}
```