COMMON TOOLS INTERFACE (CTI)

Scalable Tools Workshop

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Agenda

- Overview of Cray debugging toolbelt
  - Learn about what is available on Cray systems
- MPIR discussion
  - Why a new solution is needed
- Brief intro to CTI

- Github link to CTI repo: https://github.com/common-tools-interface/cti

CRAY

PROGRAMMING ENVIRONMENT

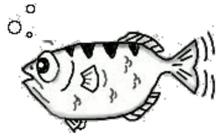
CRAY DEBUGGING TOOLS

From 30,000 feet

Cray debugging tools overview

- **Commercial third party debugging products**
  - Forge toolsuite from ARM/Allinea
  - Totalview debugger from RogueWave
  - Available on Cray systems

Cray debugging tools overview

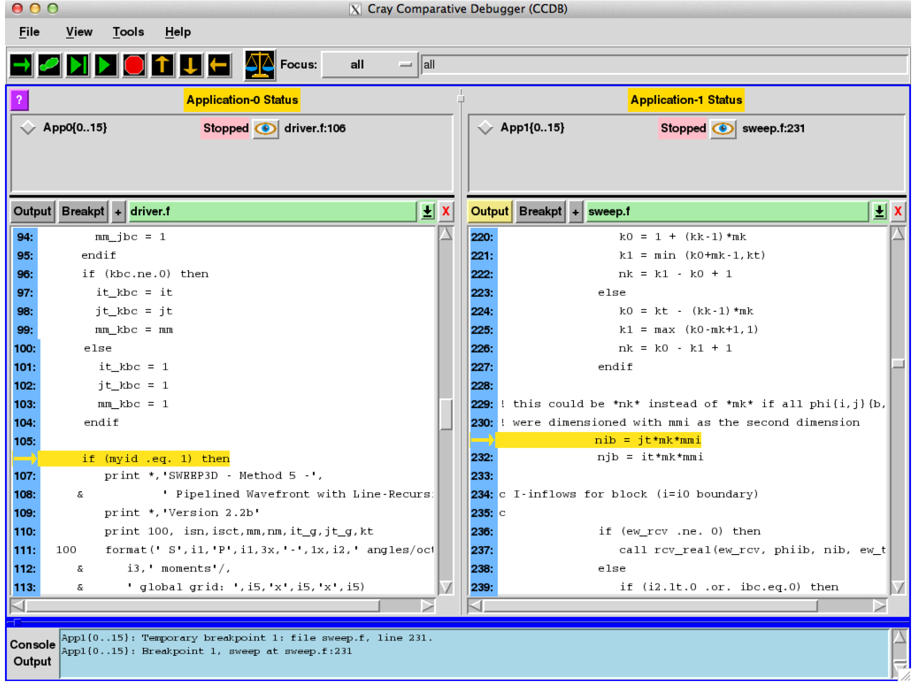
- **Gdb4hpc** 
  - Conventional CLI based interactive parallel debugger
  - Look and feel of gdb – syntax is inspired by gdb!
  - Debug your application at scale
- **Valgrind4hpc** 
  - Parallel valgrind based debugging tool (memcheck)
  - Aids in detection of memory leaks and errors in parallel applications
  - Aggregates like errors across PEs/threads

Cray debugging tools overview

- **STAT** (**S**tack **T**race **A**nalysis **T**ool)
  - Scalable generation of a single merged stack backtrace for the application
  - Open source tool from LLNL
  - GUI based tool (`stat-gui/stat-view`) along with cli tools (`stat-cl`)
  - Cray contributes code changes back upstream (ARM port)
  - Gain insight into application behavior at a function level
- **ATP** (**A**bnormal **T**ermination **P**rocessing)
  - Scalable core file generation and analysis when application crashes
  - Generates a merged stack backtrace akin to stat
  - Selection algorithm to dump unique core files

Cray debugging tools overview

- **CCDB** (**C**ray **C**omparative **D**e**B**ugger)
  - NOT a traditional debugger!
  - Compare two applications side-by-side
    - Focus on the data – not state and internal operations
  - GUI tool that interacts with gdb4hpc



Tool infrastructure

- **CTI** (**C**ommon **T**ools **I**nterface)
  - Single API to support tools across all Cray systems
  - WLM agnostic – write to API once, add WLM implementation in API
  - Application placement information, launch tool daemons on compute nodes
- **MRNET** (**M**ulticast **R**eduction **NET**work)
  - Scalable communication library for tools
- **Paradyn**
  - Dynamic instrumentation libraries

What's supported?

- **Shasta/XC**
  - All tools are supported on XC systems
  - These tools will continue to be supported on Shasta
  - User interaction will be the same on Shasta as it is today
- **Clusters**
  - Gdb4hpc, valgrind4hpc and CCDB only
- **Tools are compiler/network agnostic at their core**
  - Sockets for communication
  - Standard DWARF debug_info

WHY A COMMON TOOLS INTERFACE?

Towards a Common Tools Interface

- **Problem**: Cray needs to support several tools across diverse ecosystems
  - Multiple product lines
    - High end HPC systems like Shasta/XC/XK
    - Traditional cluster systems from the CS line
  - Multiple workload managers
    - ALPS based
      - PBS/Moab
    - SLURM based
    - Requests for many more!

What about MPIR?

- **State of the art**: MPIR
  - Good solution for its time!
- **Problematic in current era of HPC**
  - Required to attach onto the starter process
  - Multiple simultaneous tools?
  - Efficiency/scalability issues

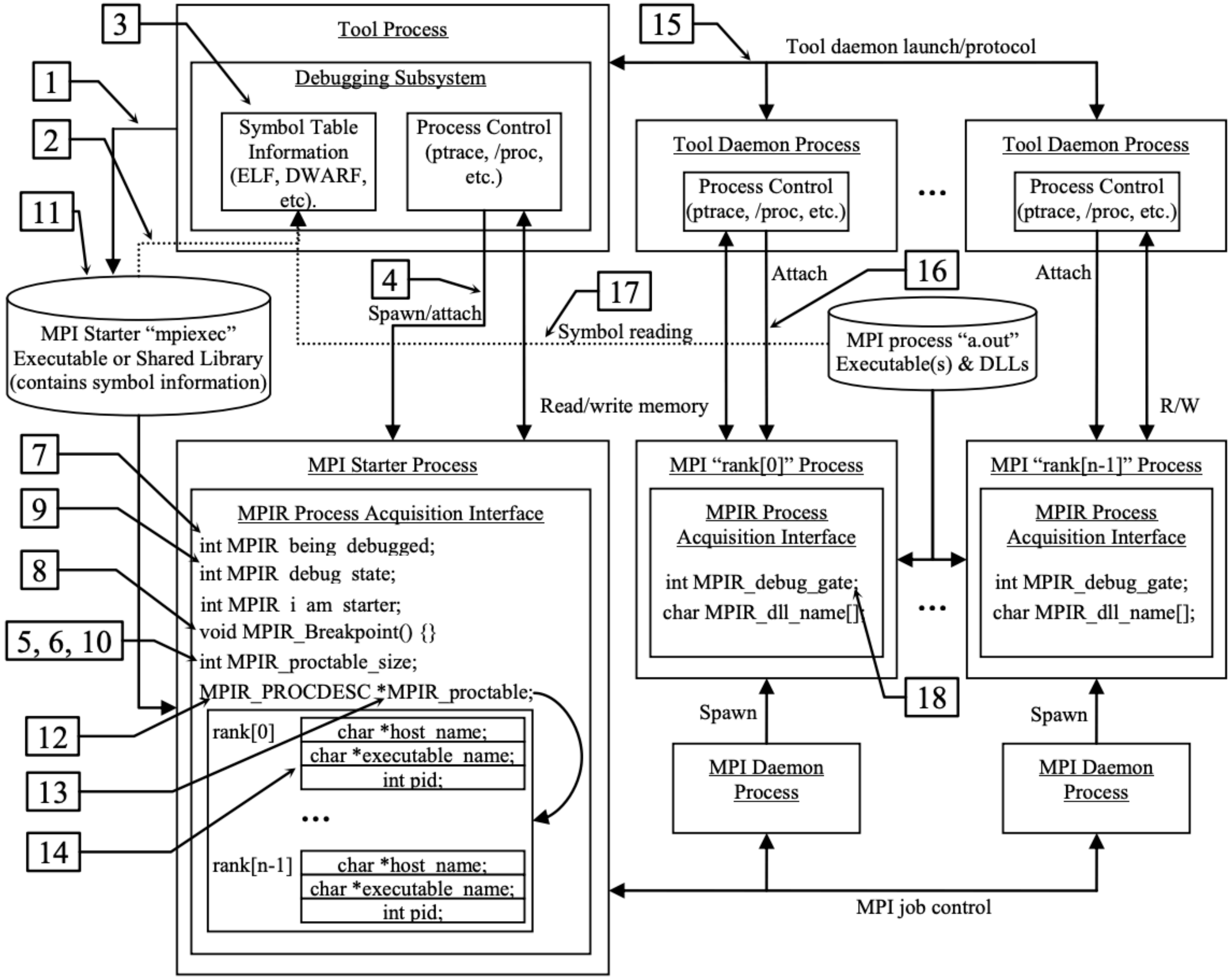


Figure 8.1: Example collaboration diagram for MPIR Process Acquisition Interface

What about MPIR?

- **Efficiency/scalability issues**
  - Requires placement data to be in-process

  - Read by Tool FE via ptrace (bad) or /proc/<pid>/mem (better)
  - Alternative: read directly from WLM DB instead
  - **Consider**
    - **Debug attach case**: Application is running in a batch script, attach onto application from another terminal
    - Need to connect to node where starter process is running in order to bootstrap!

What about MPIR?

- **Efficiency/scalability issues (cont.)**
  - Data requirements are unnecessary
    - Requires a `MPIR_PROCDESC` entry for each PE
    - ~22 MB of overhead at 1M PEs from struct alone
  - Efficient implementations will store only unique host_names/executable_names
    - What about thousands of simultaneous jobs?

```
typedef struct {
  char *host_name;
  char *executable_name;
  int   pid;
} MPIR_PROCDESC;
```

What about MPIR?

- **Efficiency/scalability issues (cont.)**
  - Cray tools care more about placement on the FE versus obtaining executable names/pids
    - Number of unique compute nodes
    - Hostname of each unique compute node
    - Number of PEs placed on that compute node
  - Obtain pid/exec path directly on compute node
  - **Approach**
    - Scale with number of compute nodes vs Pes
    - Better scaling with modern HPC systems

```
typedef struct {
  char *host_name;
  char *executable_name;
  int   pid;
} MPIR_PROCDESC;
```

```
typedef struct
{
    char *   hostname;
    int      numPes;
} cti_host_t;

typedef struct
{
    int              numHosts;
    cti_host_t *     hosts;
} cti_hostsList_t;
```

What about MPIR?

- **Tool daemon launching**
  - Extension exists to MPIR!
    - **OPTIONAL** 👎
  - Clunky interface
    - Write a variable via debugger to launch tool daemon
    - No generic interface for projecting files to computes
      - Use lustre/NFS??? Doesn’t scale for DSO lookup!
    - No way to control tool daemon specific environment
  - SSH directly to node vs srun vs alps toolhelper vs ???
    - Implement N different ways for launching tool daemons…

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WHAT IS CTI?

What is CTI?

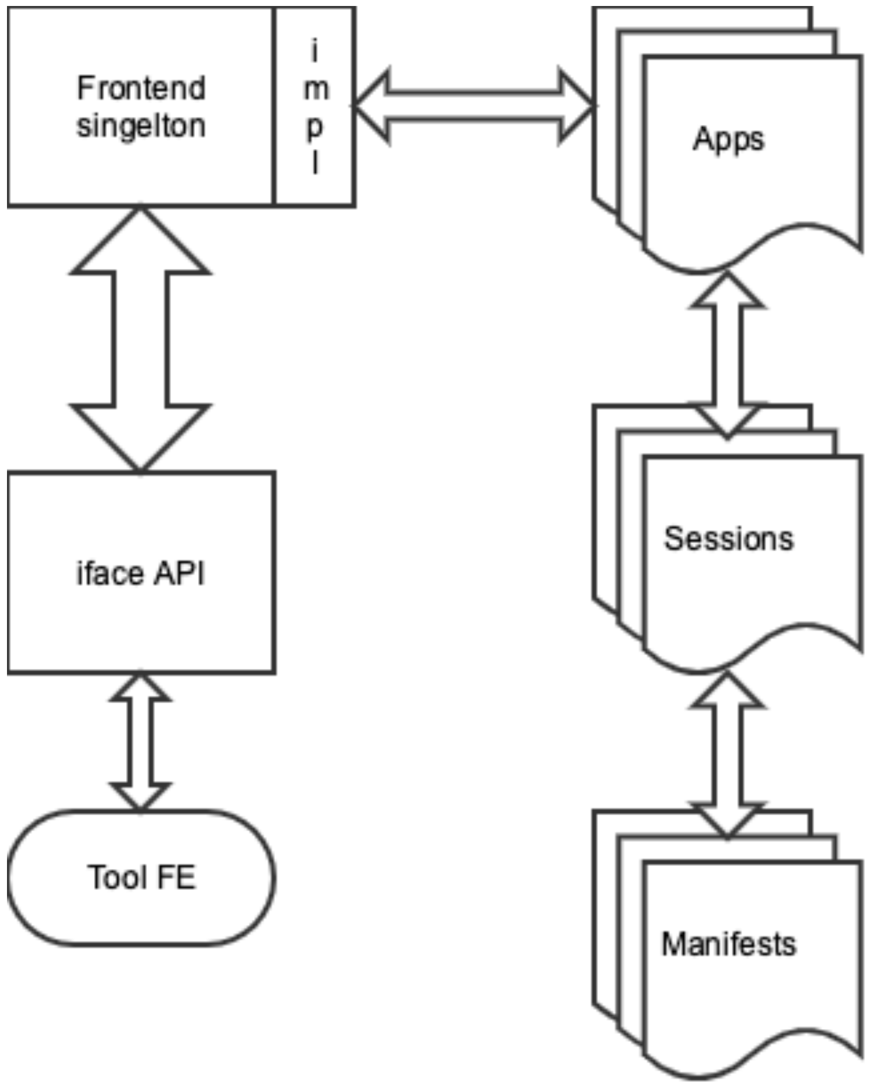
- **The Common Tools Interface aims to provide an API that provides…**
  - Way to query information about an application
  - Launch tool daemons alongside an application
    - Project binaries, libraries, and files alongside tool daemons
    - Setup tool daemon specific environment
    - Unique storage location for writing files (e.g. TMPDIR)
    - Allow for multiple tool daemons to co-exist
- **All while being implementation agnostic…**
  - Take care of common bootstrapping code that tool writers don’t necessarily care about

Towards a common interface

- CTI started as a side project in ~2011
  - **Goal**: Explore possibility of rapid prototyping of new tools
- Became CDST component in ~2013
  - Cray started supporting SLURM systems
  - Both ALPS and SLURM made things tricky for tools
  - Multiple code pathways – YUCK!
  - Porting our tools to use CTI saved development cycles and maintenance costs over time
- Stand alone cray-cti module in ~2015
- **TODAY**: Re-written in C++ on FE and open sourced (available on github)

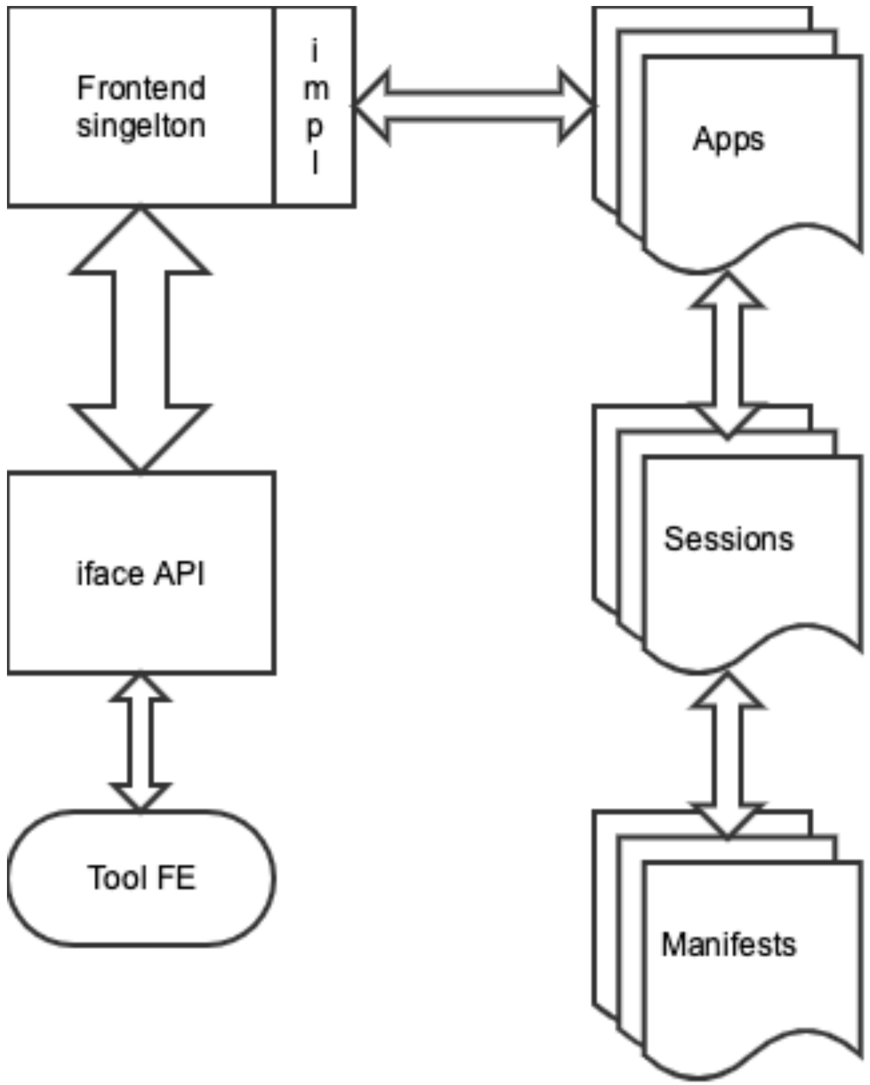
CTI FE architecture

- **Key object concepts**
  - **fe_iface**
    - C interface defining actual API
  - **Frontend**
    - Singleton object matching system type
    - Abstract base class requires real implementation to be provided
  - **App**
    - Represents application either registered or launched via API calls



CTI FE architecture

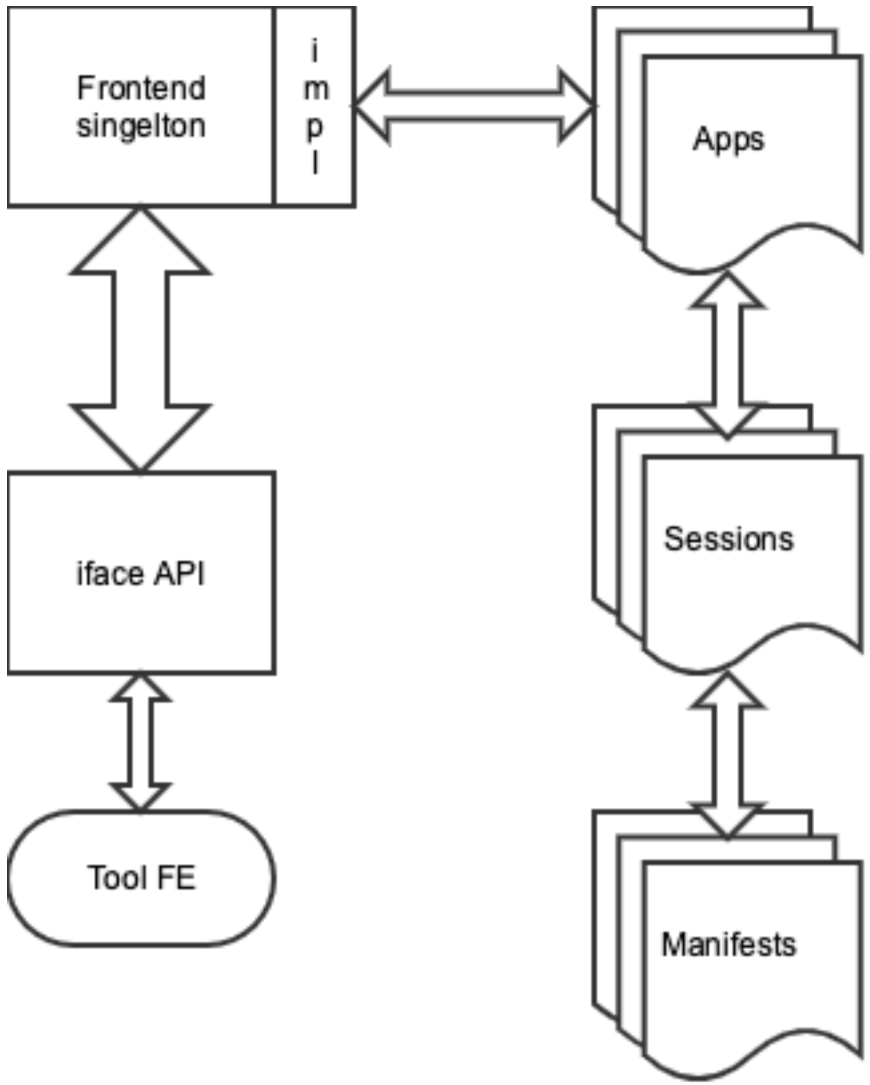
- **Key object concepts (cont.)**
  - **Session**
    - Represents a remote location on compute nodes
    - Stores state about what has previously been projected into session
    - Multiple tool daemons can share a session
  - **Manifest**
    - List of binaries, libraries, and files to be projected to compute nodes



CTI FE architecture

- **Key object concepts (cont.)**
  - **Ownership hierarchy**
    - Frontend owns associated apps
    - Apps own associated sessions
    - Sessions own associated manifests
    - When parent object destructed, all owned objects also destructed
  - **Iface mapping**

```
typedef int64_t cti_app_id_t;
typedef int64_t cti_session_id_t;
typedef int64_t cti_manifest_id_t;
```



CTI FE interface – Application launch/register

- A `cti_app_id_t` is required to do (almost) anything

```
cti_app_id_t cti_launchApp( const char * const  launcher_argv[],
                            int                 stdout_fd,
                            int                 stderr_fd,
                            const char *        inputFile,
                            const char *        chdirPath,
                            const char * const  env_list[]);
```

- Launch with barrier variant also provided
- WLM extensions provided via `cti_open_ops()` for registering an existing app

```
typedef struct {
    cti_srunProc_t* (*getJobInfo)(pid_t srunPid);
    cti_app_id_t    (*registerJobStep)(uint32_t job_id,uint32_t step_id);
    cti_srunProc_t* (*getSrunInfo)(cti_app_id_t appId);
} cti_slurm_ops_t;
```

CTI FE interface – query placement info

- Once a `cti_app_id_t` is obtained can query placement info

```
cti_hostsList_t * cti_getAppHostsPlacement(cti_app_id_t app_id);
```

```
typedef struct
{
    char *   hostname;
    int      numPes;
} cti_host_t;

typedef struct
{
    int             numHosts;
    cti_host_t *    hosts;
} cti_hostsList_t;
```

CTI FE interface – Session

- Need a session handle to launch tool daemons
  - No communication occurs in our implementation
  - API allows underlying implementations to do so if needed
  - `cti_createSession()` requires owning `cti_app_id_t`

```
cti_session_id_t cti_createSession(cti_app_id_t app_id);
```

CTI FE interface – Manifest

- Need a manifest to build a list of dependencies required by tool daemon
  - `cti_createManifest()` requires owning `cti_session_id_t`

```
cti_manifest_id_t cti_createManifest(cti_session_id_t sid);
```

- Once created, add dependencies to manifest

```
int cti_addManifestBinary(cti_manifest_id_t mid, const char *fstr);
```

```
int cti_addManifestLibrary(cti_manifest_id_t mid, const char *fstr);
```

```
int cti_addManifestLibDir(cti_manifest_id_t mid, const char *fstr);
```

```
int cti_addManifestFile(cti_manifest_id_t mid, const char *fstr);
```

- `cti_addManifestBinary()` adds dso dependencies by default

CTI FE interface – Tool Daemon Launch

- Use `cti_execToolDaemon()` to asynchronously launch a tool daemon alongside application

```
int cti_execToolDaemon( cti_manifest_id_t    mid,
                        const char *         fstr,
                        const char * const   args[],
                        const char * const   env[]);
```

- Requires a valid cti_manifest_id_t even if there are no additional dependencies
- `fstr` tool daemon binary implicitly added to manifest
- Synchronous launch mechanism for future work
  - Would allow error checking

CTI BE interface

- BE iface used to obtain information about that node
  - Link against tool daemon binary launched via `cti_execToolDaemon()`
  - Obtain application PIDs

```
cti_pidList_t * cti_be_findAppPids(void);
```

```
typedef struct
{
        pid_t                pid;     // This entries pid
        int                  rank;    // This entries rank
} cti_rankPidPair_t;

typedef struct
{
        int                      numPids;
        cti_rankPidPair_t *      pids;
} cti_pidList_t;
```

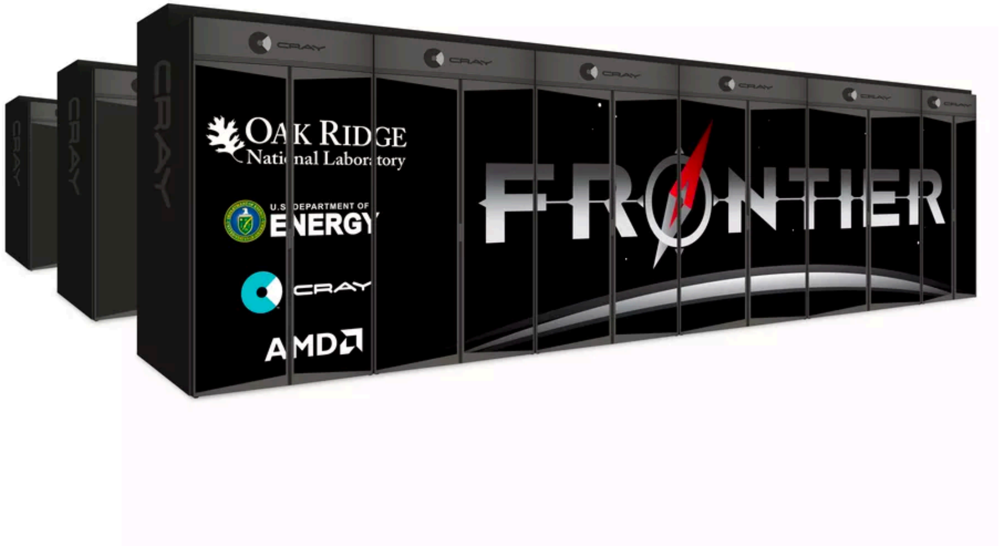
Future work

- **Community involvement as MPIR replacement**
  - If tools begin adopting this interface, better chance of new WLM implementors providing a reference CTI implementation for their ecosystem
  - Provides simple examples of tool requirements for bootstrapping
- **Add TBON communication layer**
  - Ability to gather error information
  - Scalable projection
  - Persistent TBON shared between tools?
- **Additional BE APIs to determine system capabilities**
  - Am I on a GPU node?

Wrap up

- Lots of material left uncovered!
  - Basic examples exist in tests/examples
- common-tools-interface org on github
- Reach out with any questions

- **Cray is hiring!**
  - Many positions open in PE



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