Software Requirements Specification

For

INTEgrated code generation and paraLLelization (INTELL)

Version 1.0 approved

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Table of Contents

Table of Contents ii

Revision History ii

1. Introduction 1

1.1 Purpose 1

1.2 Document Conventions 1

1.3 Intended Audience and Reading Suggestions 1

1.4 Product Scope 2

1.5 References 2

2. Overall Description 3

2.1 Product Perspective 3

2.2 Product Functions 3

2.3 User Classes and Characteristics 4

2.4 Operating Environment 5

2.5 Design and Implementation Constraints 5

2.6 User Documentation 6

2.7 Assumptions and Dependencies 6

3. External Interface Requirements 6

3.1 User Interfaces 6

3.2 Hardware Interfaces 7

3.3 Software Interfaces 7

3.4 Communications Interfaces 7

4. System Features 7

4.1 Command Line Interface 8

4.2 Web Interface 8

4.3 CUDA Kernels 9

4.4 Graphs 9

4.5 Serial to Parallel Code 10

5. Other Nonfunctional Requirements 10

5.1 Performance Requirements 10

5.2 Safety Requirements 11

5.3 Security Requirements 11

5.4 Software Quality Attributes 11

5.5 Business Rules 12

6. Other Requirements 12

Appendix A: Glossary 13

Appendix B: To Be Determined List 13

Revision History

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| **Name** | **Date** | **Reason For Changes** | **Version** |
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# Introduction

## Purpose

INTELL stands for INTEgrated tool to paraLLelize and evaluate serial code. It is part of a project that is intended for the automated conversion of serial code to the optimized parallel code. INTELL utilizes an underlying polyhedral loop transformation and code generation framework called CUDA-CHiLL, which takes Transformation Strategy Generator (TSG) generated strategies as input and produces CUDA code. INTELL also represents graphical comparison between serial code and the optimized parallel code.

## Document Conventions

In this document hence forth “This project” and “This product” refer to INTELL.

Hence forth “This Document” refers to the Software Requirements Specification of INTELL.

## Intended Audience and Reading Suggestions

The intended audience of this document includes researchers and developers working in GPU technology, evaluators for this project and other potential users interested in GPU research.

### Researchers:

This document is intended for the researchers and scientists as they are the actual or end users of INTELL. These users should read the product scope, overall description and features sections of this document.

### Project Manager:

This document is meant as guideline for this project’s project managers to ensure that the project conforms to the user requirements .The project managers should read this document sections as purpose, project scope, product perspective, product functions ,design and implementation details , system features and business rules.

### Testers:

The recommended reading order of this document for testers is purpose, product perspective, product functions, design and implementation details, system features and other non-functional requirements sections respectively.

### Evaluators:

This SRS document is describing the specifications of INTELL that shall provide interface to CUDA-CHILL and display graphical comparison of different benchmarks. INTELL is meant as a Final Year Project; hence the evaluators are expected as primary intended audience of this document.

### Developers:

Developers interested in this project for research and development should read the product scope and overall description sections of this document.

## Product Scope

The final product shall enable the users to utilize the GPU on the server for research purposes by allowing them to test generated code of commonly used benchmarks on specified GPUs without obtaining the expensive hardware. This will provide the users the ability to conduct their research through a Web Interface thus providing portability.

The product will also provide a test bed to the users which will allow them to compare the parallelization of code and give them a measure of optimization through parallelization. The product will utilize the CUDA-CHILL Framework for automated production of parallelized CUDA-Code from serial ‘C’ code, tailored for the GPU on the server.

The goals it shall achieve are

* It will provide a Graphical User Interface for CUDA-CHILL.
* It will provide a test bed for comparing the code.
* This middleware will act as a mediator between user and the backend framework on the server.
* The interface will be Web Based Interface thus providing increased portability to the user.

Main advantages that could be achieved from this system are

* Comprehensive test bed.
* Easy parallelization of serial code.
* Promote access to services through Web Interface.

## References

* Autotuning, Code Generation And Optimizing Compiler Technology for GPUs by Malik Muhammad Zaki Murtaza Khan.
* A Script-Based Autotuning Compiler System to Generate High-Performance CUDA Code by
  + Malik Khan, USC/ISI; Marina del Rey CA; National University of Science and Technology, ISB, Pakistan
  + Protonu Basu, University of Utah; Salt Lake City, UT
  + Gabe Rudy, University of Utah; Salt Lake City, UT
  + Mary Hall, University of Utah; Salt Lake City, UT
  + Chun Chen, University of Utah; Salt Lake City, UT
  + Jacqueline Chame, USC/Information Sciences Institute; Marina del Rey CA
* ISO 9241-11:1998
  + Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 11: Guidance on usability

# Overall Description

## Product Perspective

The advancement in GPU technology can be attributed mostly due to heavy investment in gaming industry. This has led to a need to use GPUs for high performance computing, for example GPUs have become an irreplaceable component of the world’s most powerful super computers. The use of NVIDIA’s GP-GPU by commercial products such as Adobe Photoshop CS6 adds to the validity of this argument. One important issue using GPU technology is that the advancement in architecture is progressing very rapidly which results in a wide variety of different architectures. To utilize these GPUs to their optimal potential, the software must be optimized according to these varying architectures. This can be a tedious and time consuming process. One of the solutions to this predicament is to provide automated conversion and testing of existing software components to different architectures. To achieve this, several different approaches have been provided. One of the most promising among these is the CUDA- CHILL framework, which parallelizes the sequential C code and optimizes it for different architectures.

INTELL shall utilize CUDA-CHILL framework to provide a web interface that would be used by researchers to optimize and test different benchmarks for different GPU architectures. It shall provide the researchers with test results of the optimization achieved under different configurations. This shall lead to better optimizations for code recipes used in software development.

## Product Functions

This product shall allow the users of this product to perform the following functions.

* The System should be accessible via web interface.
* The System shall provide support for the 6 benchmarks currently supported by CUDA-CHILL.
* The System shall calculate the results (running times of different benchmarks with custom parameters provided by the user) and provide formatted results in the form of graphs and charts.
* The system shall provide the user with downloadable results.
* The system shall allow the users to create user accounts and login with those accounts.
* The system shall generate optimized parallel code recipes for each benchmark custom generated to each GPU on the server.
* The system shall run the test calculations for a particular benchmark with user provided parameters on a specified GPU on the server.

### Use Case Diagram

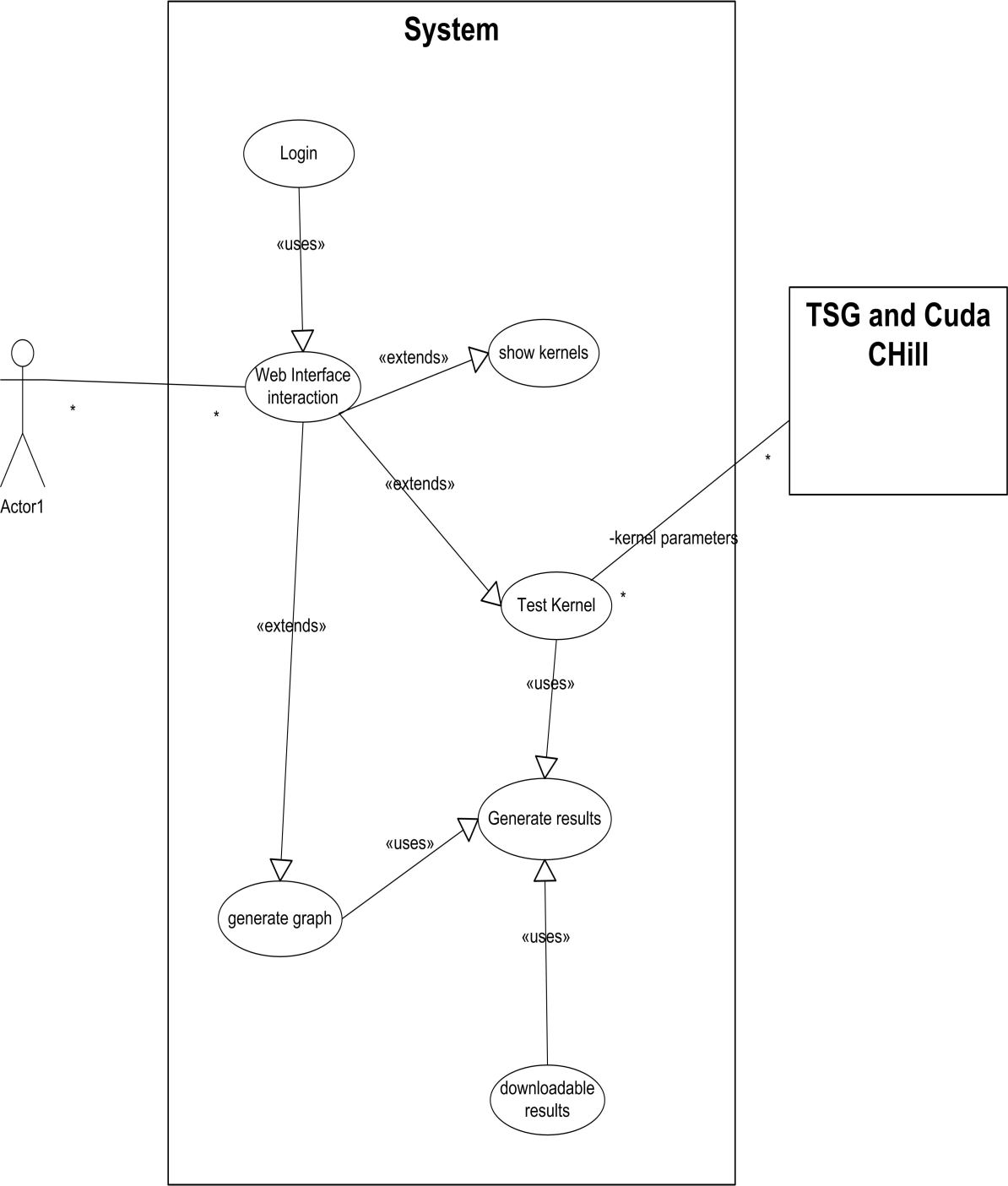
****

Figure 1

## User Classes and Characteristics

Users shall include

* Students
* Evaluators
* Scientists and Researchers

### Students

Students researching in GPU programming will be able to understand the architecture of GPUs and GPU programming by understanding and working with INTELL. They will also be able to understand the proper application of parallel and serial code.

### Evaluators

Evaluators are intended to verify and validate the product and its functionalities with respect to the required specifications. This product will initially be evaluated by the project supervisor. Functionalities and required specifications shall be verified and validated by the Panel of Evaluators.

### Scientists and Researchers

This software is meant for the Scientists and Researches. They will be able to use this product to convert their Serial C Code into an Optimized Parallel Code. The efficiency of Optimized Parallel Code will then be compared with that of Serial C code to help the scientists understand the difference.

## Operating Environment

The system requires a Linux based environment recommended environment is a Ubuntu 12.04 OS with an apache server set along with SUIF of Stanford University, along with OMEGA and CUDA-CHILL installed as direct dependencies. This will serve as the server machine. The Ubuntu shell will be used for command line instructions to server programs. There will be Nvidia graphic cards employed on server machine being accessed through shell commands to CUDA-CHILL framework. The server machine is expected to be Intel i5 or i7 processor working along with Nvidia GPU. Apache server will offer the web environment for serving user requests.

The client machine however just requires a web browser and an internet connection. It requires client to have a compatible browser preferably Mozilla Firefox 11.0 and any operating system is supported. The mobile client is expected to be a mobile browser accessing the website from GPRS of GSM service provider or wifi service. The project does not require client to have any advanced computing machine.

## Design and Implementation Constraints

CUDA-CHILL requires a Linux OS for operation and this limits the choices for server side technologies that we can use, due to this we have chosen apache as a likely candidate, which also implies that we have to use PHP as server side programming language.

* For now CUDA-CHILL is compatible with Nvidia’s GPUs so that is also a constraint.
* CUDA-CHILL has direct dependencies on SUIF and OMEGA which are compatible only with a Linux based OS.
* The customer’s organization will be responsible for maintaining the delivered software.
* Since INTELL is a web based system it shall require a client server based architecture design.
* CUDA-CHILL currently only supports a limited set of benchmarks so the users must choose from these benchmarks and provide appropriate custom parameters instead of providing their own code.
* Also due to limited number of GPUs on the server the number of concurrent users at any given time shall be small.
* This software demands a client server architecture due to the requirement of a web based application.

## User Documentation

A user manual shall be made available on the website host the web interface for his product. It shall provide a walkthrough about using the system with screenshots to facilitate the understanding of the instructions.

## Assumptions and Dependencies

The assumptions made at the time of formulating this document regarding this project include

* The software dependencies of INTELL are as follows and it is assumed that they shall be compatible with the hardware namely NVIDIA's GPUs. The list of software include
* Ubuntu 12.04.3
* SUIF
* OMEGA
* Lua

The above listed software is direct dependencies of the CUDA-CHILL framework which in itself is a direct dependency and off the shelf component of INTELL.

* INTELL shall also use Apache as a server for the web interface; hence apache is also a dependency for INTELL.

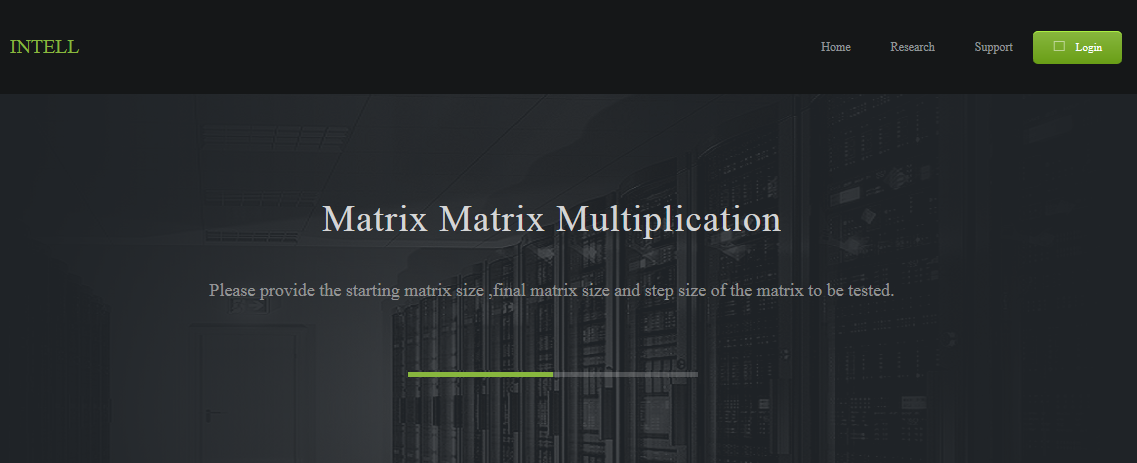
# External Interface Requirements

## User Interfaces

There shall be a tutorial available on the website as part of the web interface that shall guide the user on basic interaction scenarios with the system.

The user interfaces shall be designed while keeping in mind the user goals and other Human Computer Interaction guidelines as specified in ISO 9241-11. The user interfaces shall be evaluated in context to user goals on the basis of effectiveness and efficiency in achieving those goals.

The system shall prompt the user with error messages only on activities that might cause the system to fail. In other situations the system shall only give warning messages because the expected users of the system are researches and the need to be allowed to conduct their research unhindered.



Sample Prototype Screenshot for UI

Figure 2

## Hardware Interfaces

CUDA-CHILL currently is compatible with Nvidia’s GPUs so INTELL shall only support those kernels. The low level hardware interaction with the GPUs is handled by CUDA-CHILL through SUIF and OMEGA so is beyond the scope of this document.

## Software Interfaces

The systems SUIF and OMEGA interface with Ubuntu on one side and CUDA-CHILL which in turn interacts with a PHP server which shall interact with the client through the internet through client server architecture.

## Communications Interfaces

The client shall access the web interface (website) through the HTTP protocol and interact with this application only through the said web-interface.

# System Features

The major features of the software end product shall include following:

## Command Line Interface

### Description and Priority

A stand-alone command line interface shall allow access to a script which is able to communicate with already existing CUDA-CHILL scripts and as well as easily accessible through a web programming language. This command line interface (CLI) utility is most critical since it will not only allow web interfaces to interact with scripts on Server machine but also an abstract layer which allows for adding more features or scripts in later years of research.

Priority: High

### Stimulus/Response Sequences

Whenever user initiates a process which involves interacting or sending commands to CUDA-CHILL scripts, this CLI utility will be called via an “exec” function in PHP. This utility will output the results in a specified directory and typically requires kernel name/type, problem size and output directory which can be set to default.

### Functional Requirements

FR1: A script running on the server that shall expect following parameters through CLI

* + a benchmark name as first parameter
  + a list of parameters specific to the benchmark as second parameter.

FR2: This script shall invoke the TSG and create a result file as output

This result file shall contain

* + GPU model no and vendor information.
  + CPU model no and vendor information.
  + Average running time for benchmark on GPU and CPU for each problem size.

## Web Interface

### Description and Priority

A web interface which is served to each client requesting use of the services. The web interface is expected to be responsive to accommodate the mobile browsers as well as desktop browsers.

Priority: Medium

### Stimulus/Response Sequences

User will request browser for web interface by entering the URL of website and Apache server will reply back with web page which is then displayed by web browser.

### Functional Requirements

FR3: The system shall be accessible via web interface using http.

FR4: The system shall make results available as downloadable single file to user.

FR5: User will request browser for web interface by entering the URL of website and Apache server will reply back with web page which is then displayed by web browser.

### Description and Priority

This category includes the currently present six CUDA-CHILL kernels which are available to user for testing and comparing results based on different problem sizes. These kernels range from mathematics to biological sciences. There are six CUDA kernels for the scope of this project.

Priority: High

### Stimulus/Response Sequences

Problem or sample size are given as input to these kernels via CLI utility and these kernels after running and giving numerical values give control back to CLI. The numerical values are then used to give graphical representations.

### Functional Requirements

The kernels that shall be available on INTELL are

FR6: NBody simulation kernel

FR7: MPEG4 kernel

FR8: Matrix Matrix Multiplication

FR9: Matrix Vector Multiplication

FR10: 2D Convolution

FR11: MRI Kernel

## Graphs

### Description and Priority

The system must be able to represent all data whether it be obtained from running a kernel with CUDA-CHILL or benchmark data, in a graphical manner so the researcher is able to make a decision based on it.

Priority: Medium

### Stimulus/Response Sequences

The user requests for graphical output of problem with some sample size. These graphs are then shown to user via web interface as well as available to be downloaded by user so he is able to interpret results by other methods if required (which might involve custom graphs).

### Functional Requirements

FR12: Test system shall be able to generate graphs based on the data in the results file generated by CLI.

FR13: The system shall support the following graphs.

-Bar Chart

-Line Chart

## User Management

### Description and Priority

This feature is responsible for the management of users who will interact with system to submit testing requests with problem size for required kernel. The system shall be able to maintain user tests history. User shall be able to sign up and mailed his reports after authentication with their login ID and password.

### Stimulus/Response Sequences

User signs up using signup form and entering their name, contact email and contact number. Their profiles are then created and are allowed to update their information after signed up. The user shall be mailed their test reports after test is completed.

### Functional Requirements

FR14: The system shall allow users to sign up using their name, email id, password and phone number.

FR15: The system shall allow users to login using their email id and password.

FR16: The system shall allow users to send email to user on his email id once the test is completed.

## Serial to Parallel Code

### Description and Priority

This feature is involved with conversion of serial code into a parallel code. The user will be provided with fix set of six kernels and their codes but user can modify the sample problem sizes. The parallelized c++ code for a kernel will be shown as output to user.

Priority: Medium

### Stimulus/Response Sequences

User requests a specific kernel to be run along with problem size and its corresponding parallel code will be generated. This parallel code is accessible via web interface.

### Functional Requirements

FR17: The system should display to user the corresponding parallel code for their serial code of selected kernel.

# Other Nonfunctional Requirements

## Performance Requirements

The system should ensure that each GPU is tasked with one request at a time so that the results are as reliable as possible.

The response time of the system without including the time for the actual test should be under 1 minute with a 1mbps connection. Since the time for the actual test is highly co-related to the given problem parameters so that time cannot be included in calculation of the systems general response time.

## Safety Requirements

Backup power for the hardware must be ensured because sudden power interrupts might cause the costly hardware to malfunction as well as damage the results; the system requires at least 650Watt power with 50Hz frequency of AC current and UPS needs to have 25A max current threshold. The server must be properly cooled using cooler of 240mm. A user may submit one request at a time for processing since the wait queue is limited to maximum 20 requests. Passwords of the users must be must be kept safe using MD5 hashes.

## Security Requirements

The passwords shall not be transferred over HTTP connection but instead the MD5 hashes will be matched. The http protocol will be used for communication as the data transferred is not critical. All of the user personal information including email id and phone number shall be encrypted using AES 256 bit.

## Software Quality Attributes

* Reliability
* Each GPU must not process more than one test code recipe at a time in order to ensure maximum reliability of the results.
* The results should be repeatable on different hardware with the same specifications.
* Availability
* The system should be designed in multi-tier web architecture to increase availability.
* Maintainability
* The mean time to change should be less than 2 weeks.
* Robustness
* The system should be able to detect and recover from errors like invalid parameters for benchmarks within a 30 min time limit.
* Usability
* A user with at least a bachelor’s degree in a computer related field should be able to operate the system with less than 10 errors a day after a 2 hour training session.

## Business Rules

The users are allowed to perform tests and specify the problem size as well as iterations for single experiment. The administrator is allowed to plug-in new source codes for tests and new kernels into the system only if they have corresponding CUDA-CHILL kernels ranging from medical field to simulations. All types of users are allowed to modify their particulars such as passwords and emails. Users are allowed to download and view graphs about tests results.

# Other Requirements

The system will store user’s information and all tests results in a MySQL and the use of software system must be in accordance with license in appendix C.

Appendix A: Glossary

###### INTELL

INTEgrated tool to paraLLelize and evaluate serial code

1. CUDA-CHILL

Framework to parallelize and optimize serial C Language Code.

1. GPU

Graphics Processing Unit (embedded on Graphics Cards)

1. GPGPU

General-purpose computing on graphics processing units

1. LUA

Scripting Language

1. PHP

Web-Development Language

1. Ubuntu/linux

Operating Systems

1. CLI

Command Line Interface

1. Kernel

Module or a function in c language

1. SUIF

Stanford University Intermediate Format

1. OMEGA

Open source library similar to SUIF

1. HPC

High Performance Computing

1. MySQL

Open source Relational Database Management System.

1. NBody

Gravity field, corresponding velocity and acceleration simulations for bodies

1. MPEG4

Moving Picture Experts Group’s Audio and video compression standard.

1. 2D Convolution

A two dimensional filter for image processing.

1. MRI

Magnetic Resonance Imaging

1. MD5

Hashing Algorithm, Message Digest version 5

1. HTTP

Hyper Text Transfer Protocol

1. AES

Advanced Encryption Standard

Appendix B: To Be Determined List

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