

Educational Problem Manager Design Manual

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Notice

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1 Introduction

This document gives design information for EPM system maintainers. This document supplements but does not reiterate documentation in the EPM Help Page for users. Comments in code files in turn supplement but do not, with the exception of parameters files, reiterate this document or the Help Page.

Instructions for setting up an EPM server are in the file

`include/maintenance_parameters.php`

2 Definitions and Rules

2.1 Names

1. ***User chosen names*** consists of letters, digits, dash(-), and underscore(_), begin with a letter, and end with a letter or digit. See `/include/parameters.php $epm_name_re`.
2. ***Visible file names*** have basenames that consist of letters, digits, dash(-), and underscore(_), begin with a letter or digit, and end with a letter or digit, and optional extensions that obey same rules. See `/include/parameters.php $epm_filename_re`.
3. ***Visible problem file names*** have basenames that end with the problem name, which may optionally be preceded by a dash(-) but not by any other character.
4. Invisible problem file and directory names begin and end with plus(+).
5. Administrative files may follow other rules. In particular, email addresses have a file with a name that is the URL encoded email address, and browser tickets have a file with a name that is the 32 hex digit ticket itself.
6. ***User IDs*** and ***team IDs*** are user chosen names. An ***account ID*** is either a user ID or a team ID.
7. ***E-mail addresses*** may not have the characters <, >, ", :, or space characters.
8. A ***login name*** is either an e-mail address, or an account ID followed by a : followed by an e-mail address.

2.2 Times

1. Times are formatted as per `/include/parameters.php` which:

- defines `$epm_time_format` (defaults to "%FT%T%Z")
- sets the time zone using `date_default_timezone_set`

2.3 Account IDs

1. **Account IDs** (AIDs) are user chosen names (2.1.1)). They are unique to the account and used for both external and internal identification. Once assigned, they cannot be changed.
2. There are two kinds of AIDs: **user UIDs** for individual users, and **team TIDs** for teams (2.1.6).

2.4 Random IDs

1. A **random ID** is a 32 hexadecimal digit number, or equivalently a 128-bit number. Several are generated from `/dev/random` the first time the server is used, and thereafter they are generated as a pseudo-random sequence using previously generated values to aes-128-cbc encrypt previous values. See `/include/epm_random.php`.
2. Browser TICKETS are random IDs.
3. The **\$ID** variable is a random ID used to validate both POST and GET requests from pages.

For each tab, and sometimes for the view window, the first GET for the tab or window generates the first \$ID value for the pages that will occupy the tab or window, and also generates a random key that is used to generate a sequence of \$ID values for the tab or window by encrypting each \$ID to generate the next \$ID. Thereafter each request is checked to see if it has the right \$ID value, and a new \$ID value is generated for the next tab or window contents.

\$ID values are generated and checked by `/page/index.php` which is required by all page files (2.5.4).

2.5 Tabs and Windows

1. There are specific tabs and windows for different kinds of transactions. The **main** tab is for non-problem specific transactions. For each account problem there is a problem-specific tab for transactions on that problem. There is a **view** pop-up window for looking at files and information, and a separate **help** pop-up window for the Help and Guide Pages.

2. Pages are assigned to tabs or windows. E.g., Login, Project, User, Manage, List Edit, and Favorites Edit Pages are assigned to the main tab; Problem, Option, and Run Pages are assigned to problem tabs; the View and Template Pages are assigned to the view pop-up window; and Help and Guide Pages are assigned to the help pop-up window.
3. **Page Rule** At any given time a tab or window has a current page. The page is initially opened with a GET. Subsequent transactions on that page are done with POSTs. Each POST to a page is checked to be sure that page is the current page for its the tab or window type. So, for example, if you have opened the Project Page in the main tab, you cannot POST to the User Page.
4. **Sequence Rule** Transactions within a tab are sequenced, so that if a transaction is out of sequence the tab becomes *orphaned* and must be closed. Sequencing prevents two main tabs from existing at the same time, or two problem tabs for the same problem existing at the same time.

Sequencing is done by random sequence \$IDs that are attached to each page. The next request must contain the current \$ID else the tab is orphaned. For the main tab the Login Page initializes the tab's \$ID sequence. For problem tabs the Problem Page initializes the sequence. For the view window, the View Page initiates and uses sequencing, but other view window pages are single load pages that do no sequencing. The help window pages are .html pages that do no sequencing.

2.6 Directories

1. There are three main directories:

H, Home Directory: This is the /epm directory which is loaded from github.

W, Web Directory: This is the directory named by the EPM server URL. It contains a symbolic link to the index.php file that is the first file loaded when a user initially contacts the EPM server.

D, Data Directory: This is the directory containing all the mutable data for the EPM server.

2. The following subdirectories of H contain the EPM files that are directly visible to web clients:

H/page: Loadable page files. W/page is symbolically linked to this directory.

H/page/downloads: Example files downloadable by the client.

3. The following subdirectories of H contain the EPM files that are not directly visible to web clients:

H/include: Files that can be 'require'ed by loadable page files.

H/bin: Binary executables of programs called by loadable pages or used for off-line maintenance.

H/template: Templates used to compute client problem files from other client or project files.

H/doc: Off-line documentation files, including this file.

H/secure: Source code for binary executables involved with security.

H/src: Source code for binary executables not involved with security.

H/setup: Initial contents of D, the data directory, during EPM server setup.

2.7 Page Initialization

1. The web directory, W (2.6.1), contains the following:

symbolic link W/page \rightarrow H/page
symbolic link W/index.php \rightarrow W/page/index.php
W/parameters.php, modified copy of H/include/parameters.php
W/maintenance_parameters.php,
modified copy of H/include/maintenance_parameters.php,
(only used off-line)

2. When loaded, a page initializes by executing the following steps:

- Set \$epm_page_type to indicate the tab or pop-up window or other type. The possible values are:
+main+ and +problem+ for tabs;
+view+ for a view pop-up window that POSTs;
+no-post+ for a view pop-up window that does not POST;
+download+ for pages that download files so that <script> in /page/index.php which implements the help button is suppressed (these pages do no POSTing and have no buttons).
- If the page is the first loaded in a tab or popup-window that POSTs, then it must set \$epm_ID_init to initialize a new \$ID sequence for the tab or popup-window. Otherwise the page leaves \$epm_ID_init unset.
- The page requires /page/index.php using:

```
require __DIR__ . '/index.php'
```

3. Upon being required, /page/index.php executes the following in order:

- Computes:

```
$epm_root = ROOT
```

```
$epm_self = SELF
```

```
$epm_web = W
```

where the page currently being loaded has the URL

```
http://HOST/ROOT/SELF
```

SELF has the form `page/...`, or if not that, the form `index.php`, HOST is the EPM server host name, and ROOT is whatever is left over. Here W is the EPM server web directory (p4) and is

```
$_SERVER['DOCUMENT_ROOT'] . ROOT
```

- If SELF is either `index.php` or `page/index.php`, re-routes the request to `page/login.php`.
- Loads `W/parameters.php` which in turn defines H and D (2.6.1).
- Runs the following checks and aborts invalid requests:
 - Checks that the session is logged in, unless the page being loaded is `/page/login.php` or `/page/user/php`.
 - Checks that the client request is using the same IP address as was used for login, unless the `$epm_check_ipaddr` parameter is false.
 - Uses `EPM_ABORT` (p12) to check that no other session has been started after this session using the same AID:UID login name.
- Defines functions and error handlers.
- Except for pages of `+download+` and `+no-post+` type, checks for violations of the Page Rule (p4) and aborts violating requests.
- Except for pages of `+download+` and `+no-post+` type, initializes or checks the \$ID to enforce the Sequence Rule (p4), and re-routes violating requests to the `/page/orphan.html` page to declare the tab or window orphaned.
- Except for pages of `+download+` type and xhttp requests, defines functions and parameters for use in creating buttons and launching widows, including `<script>` functions.
- Note that many parameters and some functions are defined in `W/parameters.php`. See that file. Also see `/page/index.php` for functions it defines and button parameters it defines.

3 Data Files

Name	Format	Description	Creators	Updaters	Readers
admin	dir	administrative files	login	login user	index login user
admin/+blocking+	dir	email blocking control file p10	(editor)	(editor)	login
admin/motd.html	html	message of the day p10	(editor)	(editor)	login
admin/+lock+	lock	administrative lock file p10	(updater)	login user	(updater)
admin/+random+	lock	random number generator p11	login	login index	login index
admin/+actions+	lines	log of administrative actions p??	(updaters)	user	view
admin/browser	dir	browser tickets	login	login	login
admin/browser/TICKET	1-line	ticket info p11	login		login
admin/email	dir	email files	user	user	login user
admin/email/EMAIL	1-line	email info p11	user	login user	login user
admin/users admin/teams	dir	administrative user/team directories	user	user	user login
admin/users/UID admin/teams/TID	dir	administrative account files	user	user login	user login
admin/users/UID/ UID.login admin/teams/TID/ UID.login	lines	log of logins p11	(updaters)	login user	(index)
admin/users/UID/ UID.inactive admin/teams/TID/ UID.inactive	lines	inactive .login files p14	user		
admin/users/UID/ UID.info	json	user info p14	user	user	user
admin/teams/TID/ TID.info	json	team info p??	user	user	user

Name	Format	Description	Creators	Updaters	Readers
admin/users/UID/ +actions+ admin/teams/TID/ +actions+	lines	log of accounts's administrative actions p??	(updaters)	user	view
admin/users/UID/ manager	1-line	teams that UID manages p??	user	user	user
admin/users/UID/ member	1-line	teams of which UID is a member p??	user	user	user
admin/teams/TID/ +read-write+	UID	current read-write user p??	+main+	+main+	+main+
accounts	dir	holds account subdirectories	user	user	all
accounts/AID	dir	account subdirectory	user	problem project	all
accounts/AID/ +lists+	dir	holds account problem lists	list	list favorites	+main+ view
accounts/AID/ +actions+	lines	log of account problem related actions	(updaters)	project run	view
accounts/AID/ PROBLEM	dir	account problem directory	project	+problem+ project	+problem+ project
accounts/AID/ PROBLEM/ +actions+	lines	log of problem related actions	(updaters)	project run	view
accounts/AID/ PROBLEM/ +altered+	empty	alteration indicator p??	(updaters)	problem run	(updaters)
accounts/AID/ PROBLEM/ +changes+	lines	log of changes made by pulls	project	project	
accounts/AID/ PROBLEM/ +work+	dir	working directory for jobs	problem run	problem run	problem run
accounts/AID/ PROBLEM/ +run+	dir	working directory for runs	run	run	run

Name	Format	Description	Creators	Updaters	Readers
accounts/AID/ PROBLEM/ ...	various	files visible to users	+problem+	+problem+	+problem+
projects	dir	p??	login	maint	
solutions	dir	p??	login	maint	

4 Session Variables

Name	Description	Creators	Updaters	Readers
EPM_EMAIL	login email	login		all pages
EPM_AID	account ID	login user		all pages
EPM_UID	user ID	login user		login user manage
EPM_IS_TEAM	true iff AID is team ID	login user		index
EPM_IPADDR	session IP address	login		index login user
EPM_TIME	session time	login		index login user
EPM_ID_GEN	\$ID generation	index	index	index
EPM_ABORT	session abort info	login user		index

5 Web Pages

5.1 Login Page

Login Page Requires

page/index.php
include/epm_random.php

Login Page Files

admin/+blocking+	-	-	read
admin/motd.html	-	-	read
admin/+lock+	create	update	read
admin/+random+	create	update	read
admin/browser/TICKET	create	-	read
admin/email/EMAIL	-	update	read
admin/users/UID/UID.login	-	append	stat
admin/users/UID/GID.login	-	append	stat
admin/teams/TID/MID.login	-	append	stat

Login Page Session Data

EPM_EMAIL	create	-	-
EPM_AID	create	-	read
EPM_UID	create	-	-
EPM_IS_TEAM	create	-	-
EPM_IPADDR	create	-	read
EPM_TIME	create	-	read
EPM_ABORT	create	-	-

5.1.1 Login Page File Formats

admin/+blocking+:

Lines of format: SIGN RE

SIGN + to not block, - to block

RE regular expression matched to the entire email name
(e.g., .* matches any email name and .*\.edu matches
any email name ending in .edu)

- The lines are read in order and the first line with RE matching the login name EMAIL is used to not block or block the EMAIL. If no line matches, the EMAIL is not blocked.
- Blank lines and whose first non-whitespace character is # are ignored. Various forms of within-line whitespace are equivalent, and whitespace at beginning or end of a line is ignored.

admin/motd.html:

An HTML file that is included inside a <div>...</div> block that gives the ‘message of the day’ on the Login Page. Typically this file consists of some <p> paragraphs. If the file does not exist, the <div>...</div> block is not created.

admin/+lock+:

All transactions within the `admin` directory (i.e., all http requests that access files or subdirectories within `admin`) begin by calling the `parameters.php` LOCK function to lock the `admin` directory. This function locks the directory by creating if necessary and locking this `+lock+` file for the course of the transaction. Note there are no EPM transactions longer than a single http request.

admin/+random+:

The pseudo-random number generator in `include/epm_random.php` exclusively creates, updates, and reads this file.

admin/browser/TICKET (ticket file): T AID EMAIL

TICKET ticket proper; 32 hexadecimal digit ticket number
 T ticket type; 'c' for confirmation number; 'a' for automatic
 AID account ID:
 team ID (TID) if ticket is for team member login
 user ID (UID) if ticket is for guest login
 '-' if ticket is for user login
 EMAIL Email address (identifying user account)

- When a user initially logs in to create an account, the UID is not known when the ticket is created.

admin/email/EMAIL (regular email file): UID ACOUNT ATIME

EMAIL Email address encoded with PHP rawurlencode
 UID user ID
 ACOUNT Number of auto-login periods completed so far.
 ATIME Start time of newest (incomplete) auto-login period.

admin/email/EMAIL (pre-login email file): - TID ...

EMAIL Email address encoded with PHP rawurlencode
 TID Team user ID (may be more than one)

- This form of email file is created by the User Page when a team member is assigned the given EMAIL before the member has an account or EMAIL has been added to an existing account. The TID's list all the team IDs that might in their `TID.info` file have a member which has this EMAIL and no UID. A TID might be listed whose `TID.info` file no longer contains the EMAIL.

When the pre-login form is converted to a regular form, the list of TID's is used to convert any matching EMAIL members in `TID.info` files to UID(EMAIL) members.

admin/users/UID/UID.login (login log):

admin/teams/TID/UID.login (login log):

admin/users/UID/GID.login (login log):

Lines of format: TIME EMAIL IPADDR BROWSER

UID	User ID
TID	Team ID
GID	Guest User ID
TIME	Session time for login (EPM_TIME)
EMAIL	Email address used for login (EPM_EMAIL)
IPADDR	IP address for session (EPM_IPADDR)
BROWSER	<code>\$_SERVER['HTTP_USER_AGENT']</code> with '(...)'s removed and horizontal spaces replaced by ';'s

- A login with name AID:EMAIL is valid iff the file `.../AID/UID.login` exists for UID the user ID associated with EMAIL.
- Upon login, a line is appended to the appropriate the `.login` file, and then that file's name and modification time are stored in EPM_ABORT and used to abort a session if another session logs in with the same AID:EMAIL and appends to the file, thus changing its modification time.

5.1.2 Login Page Session Variables

EPM_EMAIL	EMAIL entered by user into browser; set by Login Page when either (1) EMAIL is to be transferred to user.php for a new user, or (2) browser sends TICKET which identifies EMAIL and EPM_UID is being set.
EPM_AID	Account ID, either user or team; set by Login Page when a valid TICKET is received, and set by User Page for new users. This equals EPM_UID for a user login, is the team ID for team member login, and is the host user ID of the EMAIL guest for a guest login.
EPM_UID	User ID associated with EPM_EMAIL. Set when EPM_AID is set.
EPM_IS_TEAM	True iff EPM_AID is team ID; Set when EPM_AID is set.
EPM_IPADDR	Set to <code>\$_SERVER['REMOTE_ADDR']</code> by Login Page when EPM_AID is not yet set.
EPM_TIME	Set to <code>\$_SERVER['REQUEST_TIME']</code> formatted by <code>\$epm_format_time</code> by Login Page if EPM_AID is not yet set.
EPM_ABORT	Set to <code>[FILE, MTIME]</code> where MTIME is the mod time of <code>\$epm_data/FILE</code> and the session must abort if the mod time of this file changes. Here FILE is <code>admin/users/AID/UID.login</code> to which a line is appended whenever EPM_AID is set for a session.

5.1.3 Login Page Transactions

1. If regular form admin/emails/EMAIL exists log existing user in and go to Project Page. The browser first gets a ticket which it sends to the server, and the ticket specifies the EMAIL.
 - (a) Browser can look EMAIL up in browser's local memory to get ticket to send to server, or if this ticket does not exist or is invalid,
 - (b) Browser can send EMAIL to server and get confirmation number back to use as a ticket.
2. Otherwise, if no regular form admin/emails/EMAIL exists, give the browser a confirmation number to use as ticket, and upon receiving this set EPM_EMAIL and give the browser a new automatic ticket and instruct the browser to go to User Page to create new user.

5.2 User

User Page Files

admin/email/EMAIL	create	update	read
admin/users/UID/UID.info	create	update	read
admin/teams/TID/TID.info	create	update	read
admin/users/UID/UID.login	-	append	stat
admin/users/UID/GID.login	-	append	stat
admin/teams/TID/UID.login	-	append	stat
admin/users/UID/UID.inactive	create	-	-
admin/users/UID/GID.inactive	create	-	-
admin/teams/TID/UID.inactive	create	-	-
admin/users/UID/manager	create	update	read
admin/users/UID/member	create	update	read
admin/users/UID/+actions+	create	append	-
admin/teams/TID/+actions+	create	append	-
admin/+actions+	create	append	-

User Page Session Data

EPM_USER	create	update	read
EPM_DATA	create	update	read
EPM_EMAIL	-	-	read
EPM_AID	create	-	read
EPM_UID	create	-	read
EPM_IS_TEAM	create	-	read
EPM_IPADDR	-	-	read
EPM_TIME	-	-	read
EPM_ABORT	create	-	-

5.2.1 User Page File Formats

admin/users/UID/UID.info (user info file):

JSON file with the following components:

'uid'	UID (PID for person, team UID for team)
'sponsor'	PID; missing if not team
'manager'	PID; missing if not team
'emails'	[EMAIL { , EMAIL } [*]]; missing if team
'members'	[MID { , MID } [*]]; missing if not team
'full_name'	TEXT
'organization'	TEXT
'location'	TEXT

where

MID	member ID; PID if available or EMAIL not yet assigned to a user account otherwise (EMAIL has 'Ø' and PID does not)
TEXT	plain text

- When a team UID.info file is created, MIDs are specified as EMAILs which are resolved if possible to PIDs.
- When a person initially creates an account, all UID.info files are searched and if any have MIDs matching the new account EMAIL, they are resolved to PIDs.

admin/users/UID/PID.inactive:

Inactive .login file, made by renaming .login when UID is no longer a member of AID team. May be reactivated.

5.2.2 User Page Transactions

1. If EPM_UID not set, get data for new user and create new user account if data acceptable.

2. If EPM_UID exists for a user account, display user data and allow it to be edited.
3. If EPM_UID exists for a team account (as discovered by reading UID.info), go to Team Page.

5.3 Problem

Problem Page Files

<code>users/UID/PROBLEM</code>	create	update	read	delete
<code>users/UID/PROBLEM/PROBLEM.tex</code>	upload	-	read	delete
<code>users/UID/PROBLEM/PROBLEM.pdf</code>	create	-	read	delete
<code>users/UID/PROBLEM/PROBLEM.c</code>	upload	-	read	delete
<code>users/UID/PROBLEM/PROBLEM.cc</code>	upload	-	read	delete
<code>users/UID/PROBLEM/PROBLEM.java</code>	upload	-	read	delete
<code>users/UID/PROBLEM/PROBLEM.py</code>	upload	-	read	delete
<code>users/UID/PROBLEM/PROBLEM</code>	create	-	read	delete
<code>users/UID/PROBLEM/PROBLEM.class</code>	create	-	read	delete
<code>users/UID/PROBLEM/PROBLEM.pyc</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.c</code>	upload	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.cc</code>	upload	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.java</code>	upload	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.py</code>	upload	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.class</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.pyc</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.in</code>	upload	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.sin</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.sout</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.fout</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.ftest</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.dout</code>	create	-	read	delete
<code>users/UID/PROBLEM/XXXX-PROBLEM.score</code>	create	-	read	delete

Problem Page Session Data

EPM_EMAIL	-	-	read
EPM_UID	-	-	read
EPM_PROBLEM	create	update	read

6 Overview

Here we list administrative files and transactions, and give a brief description of each.

6.1 Administrative Files

EPM uses administrative files to direct generation of files from other files, to keep track of visibility permissions, and for other things. All these files are in JSON format. EPM does not use any data base (like MYSQL).

Administrative files are not uploadable by the user. They are made by commands issued by the user to web pages, e.g., the **PPPP.score** file is made by the user commanding the **PPPP.run** file, and the user can make their own **...-PPPP.run** file using a web page. When administrative commands are made using a web page, the code associated with the page checks that the file being made does not violate security.

The following administrative files the user will encounter. Unless otherwise noted, these are visible to the user.

XXXX.mk

File specifying how to make the file **XXXX**, when this last file is generated from other files. E.g., the **UUUU/PPPP/00-000-PPPP.out.mk** file tells how to make the **UUUU/PPPP/00-000-PPPP.out** from the **system/PPPP/00-000-PPPP.in**, the **system/PPPP/generate-PPPP**, and **UUUU/PPPP/PPPP**.

A **XXXX.mk** file also tells how to make itself, so there is no need for **XXXX.mk.mk** files. **XXXX.mk** files are made from template files.

system/template/X.E->Y.F.tpl

Template file used to make **.mk** or other administrative files. A typical template file name ends with **X.cc->X.tpl** and is used to make a **X.mk** file that specifies how to make a **X** file from a **X.cc** file, where **X** is a parameter to the template file. In general single upper case letters are used as parameter names for template files, and may also appear in the names of the template files themselves.

Template files are located and used by code in web pages that make administrative files.

UUUU/credentials

Credential file for user. Specifies user email addresses, ip addresses, dates ip addresses last certified and last used.

UUUU/logins

Login history of user.

UUUU/PPPP/uploads

Upload history of user for problem **PPPP**. Note that a user's uploads for a problem are

automatically checked into a per-user, per-problem **git** database which can be cloned by the user and partially inspected (in particular to obtain difference listings) using EPM web pages.

UUUU/PPPP/runs

Run history of user for problem **PPPP**.

DDDD/user.perm

Permission control file for arbitrary users for all files in directory **DDDD** (e.g., in **system**, **system/PPPP**) and its subdirectories.

DDDD/UUUU.perm

Permission control file for user **UUUU** and files in directory **DDDD** (e.g., in directory **UUUU**).

In the above, **system/** is actually a project directory. There can be many project, and the **UUUU/PPPP/UUUU.perm** file can point to any of them, in place of **system/**.

6.2 Transactions

The only way a user can interact with EPM is via transactions. Each transaction is executed by entering small amounts of text on a web page and clicking appropriately.

The common transactions are:

download

Download any file visible to the user.

inspect

Inspect various visible JSON administrative files in a more readable format.

directory

Create or destroy problem directories and designate a current problem directory.

upload

Upload any program source (**.c**, **.cc**, **.java**, **.py**, or **.lsp**) file or any program input (**.in**) file into the current problem directory.

make

Create, edit, and destroy **.mk** files, whose existence causes the associated derived files to be made upon demand, in the current problem directory.

run

Create, edit, and destroy **.run** files, which define runs that cause batches of derived files to be created, in the current problem directory. Execute designated runs.

permission

Create, edit, and destroy **.perm** files that control permissions and visibility.

credentials

Inspect and remove credentials of the current user.

project

Create or destroy project directories and designate project directories that are visible to the current problem directory.

move

Move files between the current problem directory and a project directory.

Program source files do not have to be problem solution files. Any program can be run so long as it opens no files and does all its input/output via file descriptors. Program output can be put into **.out**, **.fout**, **.debug**, **.info**, or **.disp** files. The last kind of file encodes X-windows commands that can be displayed in an X-window or pdf window or placed in a **.pdf** file. Programs can also interact with terminal windows; for example, a program can be written to calculate combinations (i.e., N choose K).

Problem solution programs are run without arguments, unless they are being debugged, in which case their output is put into **.debug** files. Other programs can be run with or without arguments.