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LangMod Users Manual

by Joseph C. Collins and Linda L. C. Moss

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14. ABSTRACT

LangMod is an interactive software implementation of a modified Langlie sequential test strategy. Similar to the Up and Down (Bruceton) method, the Langlie strategy can be used in V_{50} ballistic limit testing to select test shot velocities based on previous velocities and responses. The software includes graph frames to show the data in shot sequence and the response curve as a function of velocity when the appropriate data is obtained. Parameter estimates are also provided to include the mean and standard deviation of the response curve as well as the V_{50} estimate and V_{50} standard deviation.

15. SUBJECT TERMS

quantal response, Langlie test, V_{50}, ballistics

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1. Introduction

LangMod is a software implementation of a modified Langlie sequential strategy for quantal response (all or nothing, success or failure) testing (*1*). Quantal response testing includes sensitivity testing of a system, component, or person subjected to a stress level measured on a continuous scale. A response such as success or failure is recorded, indicating whether some criterion is met or not. LangMod was implemented for use in V_{50} ballistic limit testing to select test shot velocities based on previous velocities and responses. The Langlie procedure was modified to allow gate shifts (i.e., allowing a change in the range of velocities at which to shoot) and stopping rules (*2*). Details of the procedure are described in section 9, and an example follows in section 10.

2. Quantal Response Modeling

In its basic form, the quantal response model is a regression model with a single real continuous independent variable or predictor called the stimulus (denoted x), and a single discrete dependent variable called the response (denoted y), which takes values in $\{0,1\}$ according to a Bernoulli distribution. The usual terminology is that Bernoulli failure, or $y = 0$, is a nonresponse and Bernoulli success, or $y = 1$, is a response. The Bernoulli parameter is taken to be a parametric function of x, so that

$$\Pr[y = 1|x] = \mathrm{E}[y|x] = G_\theta(x) \ . \tag{1}$$

The function $G_\theta(x)$ is called the response curve. Note that $0 \le G_\theta(x) \le 1$ for all x. A realistic and useful constraint is that $G_\theta(x)$ should be an increasing function of x, so higher stimulus levels are more likely to produce a response. Consequently, $G_\theta(x)$ has the form of a cumulative distribution function (cdf), and indeed the most common choices are the normal distribution, resulting in the probit model

$$G_o(z) = \frac{1}{\sqrt{2\pi}} \exp(-\frac{z^2}{2}) \tag{2}$$

and the logistic distribution, resulting in the logit model

$$G_o(z) = \frac{1}{1+\exp(-z)} \ , \tag{3}$$

where the standardized response curve is $G_o(z)$. The standardized argument z depends on the stimulus x through the parameter θ. Typical choices for z are polynomials in x. The basic model is a polynomial of degree 1,

$$z = a + b\,x = \frac{(x - m)}{s} \ , \tag{4}$$

so the parameter is $\theta = (a, b)$ in the linear parameterization or $\theta = (m, s)$ in the location-scale parameterization. LangMod uses a degree 1 polynomial in both models 2 and 3 and presents results in terms of the location-scale parameterization via equation 4.

$$G_\theta(x) = G_o\left(\frac{x - m}{s}\right) \ . \tag{5}$$

An experiment consists of selecting values of x, exercising the system, and collecting values of y. A sequential strategy for efficient estimation of the parameter specifies values of x based on previously observed values of x and y. Many such schemes exist (Bruceton, Up and Down, Robbins-Monro, Langlie, Neyer, etc.). As stated, LangMod uses a modified Langlie strategy algorithm.

Parameter estimation is not part of the sequential strategy but is included in LangMod. For the observed values of x and y, LangMod estimates the response curve parameters using Generalized Linear Model (GLM) techniques and also calculates elements of the parameter covariance matrix to facilitate the computations required for hypothesis testing and confidence interval construction. Discussion of GLM is beyond the scope of this report.

3. Ballistic Response (V_{50}) Modeling

The terminology of the LangMod interface is in the context of ballistic penetration testing. A threat with velocity v impacts a target, and the result is either partial penetration (PP) or complete penetration (CP). Note that a nonpenetration is a partial penetration. The stimulus is velocity v, which takes the place of x, and the response is penetration p, which takes the place of y in the model of equation 1. Bernoulli success, or $p = 1$, corresponds to complete penetration, or failure of the target. Bernoulli failure, or $p = 0$, corresponds to partial penetration, or nonfailure of the target.

The model parameter m is, in fact, the ballistic V_{50}, the velocity v at which the probability of penetration equals 0.5, since

$$\Pr[p = 1 | v = m] = G_\theta\,(m) = G_o\,(0) = 0.5 \tag{6}$$

in both the normal (probit) and logistic (logit) models. The parameter s characterizes the steepness of the ballistic response. If $s = 0$, then the response is a step function with

$$\Pr[p = 1 \mid v < m] = 0 \tag{7}$$

and

$$\Pr[p = 1 \mid v > m] = 1 \ . \tag{8}$$

Otherwise (with $s > 0$), the probability of transition from PP to CP becomes more gradual as s increases.

---

4. Software Installation

LangMod is a Java graphical user interface (GUI) program that runs on any platform (Linux, MAC OS X, or Windows) that has Java installed.

To install LangMod, copy the distribution file `Langmod_yyyymmdd.jar` to an installation directory, e.g., "C:\projects\langmod" or "/home/name/projects/langmod." This file is an executable java archive (jar file). Do not unpack it or change the extension.

On any platform, start the program from the command line in the installation directory with

```
java -jar Langmod_yyyymmdd.jar
```

or from anywhere with

```
java -jar /installation_directory/Langmod_yyyymmdd.jar
```

LangMod stores initialization, log, and session files relative to the current working directory.

In Windows, simply (right or double) click the jar file to run LangMod. For convenience, it is possible to right drag a shortcut to the Windows Desktop and adjust the starting directory as needed in the "Start in:" shortcut properties field. LangMod stores initialization, log, and session files relative to the starting directory. By default, this is the installation directory.

5. Basic Operation

LangMod presents two frames (windows). The base frame (figure 1) contains the parameter view, where the user enters initial parameters, and the experiment view, where the algorithm operates. The graph frame (figure 2) shows data and estimated response curve plots calculated in real time.

A LangMod session is a single Langlie series. Session information (identification, parameter specifications, and all analysis steps and logic) is recorded in log files. Incomplete sessions can be saved and restored.

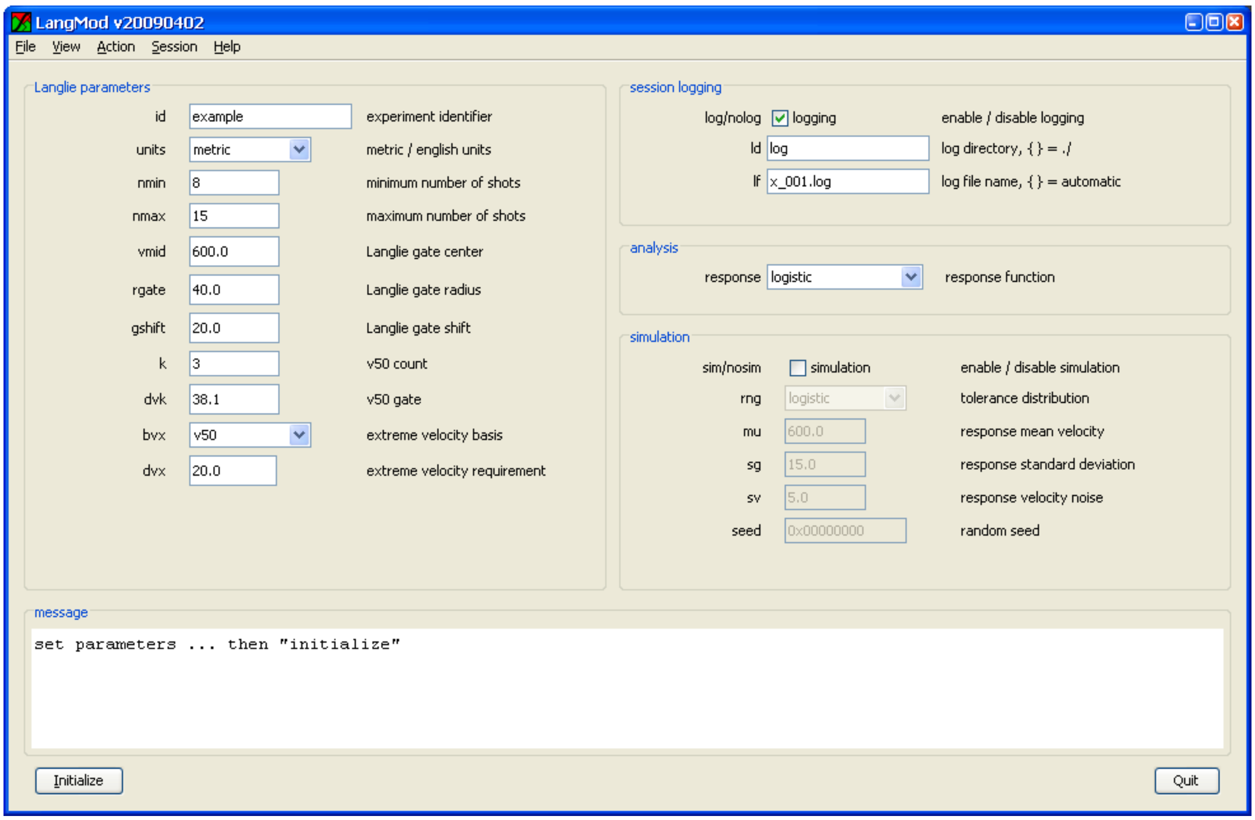

Figure 1. Parameter view in base frame.

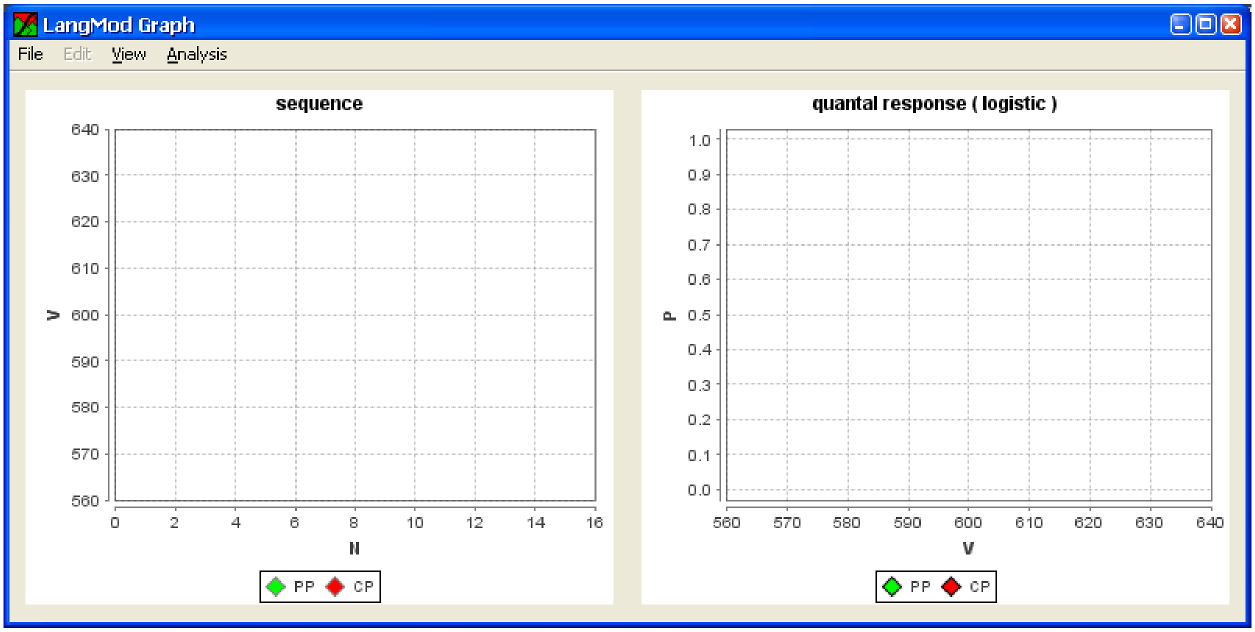

Figure 2. Initialized graph frame.

5.1 Parameter View

When LangMod starts, the parameter view is visible in the base frame (see figure 1). Parameters are set in the Langlie parameters area (upper left hand). Essentially, the algorithm tells the user what intended velocity to shoot next, depending on parameter settings and previous (observed velocity/penetration) data in the current session. The algorithm starts at `vmid` (the expected midpoint where 50% of the responses would be positive and 50% would be negative, such as an expected V_{50}) and searches within a range of test values, `vmid` ± `rgate`, where `rgate` is the gate radius giving the minimum and maximum velocities the algorithm allows. The procedure will continue for at least a minimum number of shots (`nmin`) until the termination conditions are satisfied or the maximum specified number of shots (`nmax`) has been reached. Definitions of the parameters and nominal values are given in section 6.

In the *session logging* area (upper right hand), the *logging* box should be checked. Session logs are stored in the log directory. If the log directory does not exist, LangMod will attempt to create it (relative to the LangMod directory, current directory, or starting directory). LangMod will insert an automatic sequential file name; however, replacing this with a meaningful name is recommended. LangMod will not write over an existing log file.

Under the *session logging* area are the *analysis* area, where the response model can be selected (see section 5.6), and the simulation area, where the *simulation* box should be unchecked for production use. When the settings are correct, press the *Initialize* button.

5.2 Experiment View – Preshot

Next, LangMod presents the experiment view (see figure 3). An (empty) shot log is displayed in the log area (upper left), decision criteria in the conditions area (upper right), statistics in the statistics area (mid right), strategy for the next shot in the strategy area (lower left), and instructions for the user in the messages area (lower right).

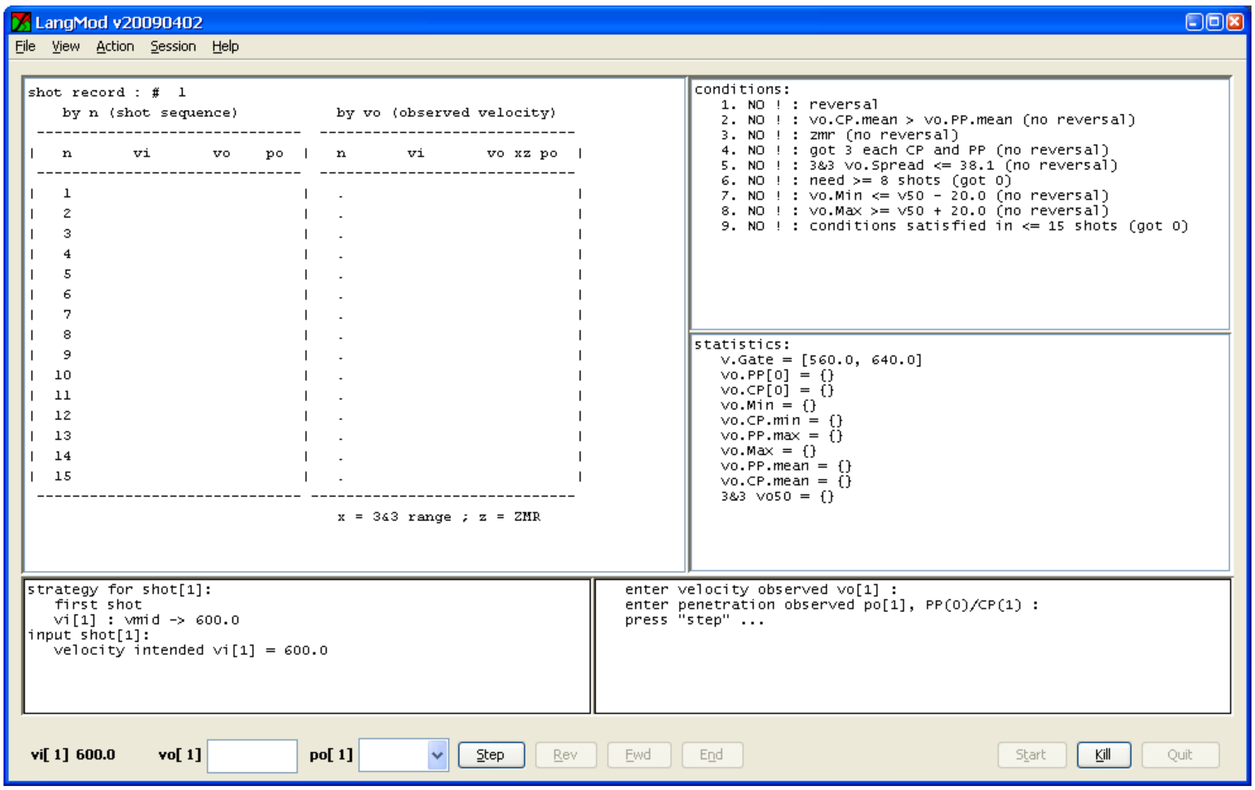

Figure 3. Experiment view – preshot.

`vi[1] 600.0` shows that the intended velocity (`vi`) for shot 1 is 600. Shoot the shot and observe the actual velocity and penetration result. Enter the observed velocity for shot 1 in the `vo[1]` box and select a penetration result from the `po[1]` pull down, either 0 for PP or 1 for CP. Then press the *Step* button.

5.3 Experiment View – In a Series

Continue the shot cycle of

- read the intended velocity
- shoot round with the intended velocity
- record observed velocity and penetration
- press *Step*

The result of several shots is shown in figure 4. The reverse (Rev) and forward (Fwd) buttons do what they say. If a mistake is made in a past entry, use the Rev button to back up. The entries will be temporarily removed from view in the shot record area, and the correct value can be entered. For example, if after shot 3, a mistake was made on entering the values for shot 1, press the Rev button three times to get back to shot 1. Correct the entry for shot 1, then press Step to register the entry. Use the Fwd button to resume the program at shot 4. The entries for shots 2 and 3 will return to the window. At any point, the *Kill* button stops the program and saves the log file.

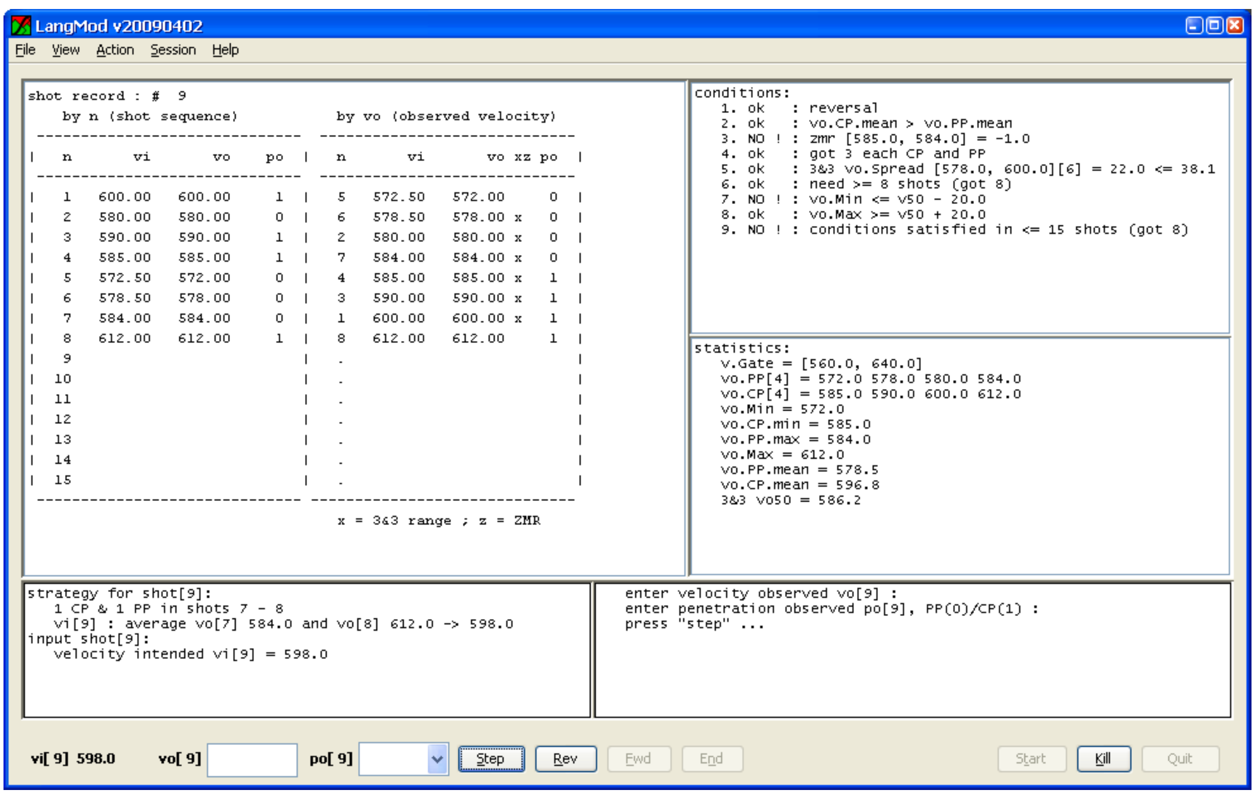

Figure 4. Experiment view – in a series.

5.4 Experiment View – Series Terminated

The series will terminate if all conditions are satisfied without exceeding the maximum number of shots, as in figure 5, or if the maximum number of shots has been reached and all conditions are not satisfied. Press *End* to end the series and close the log file. This saves the log file.

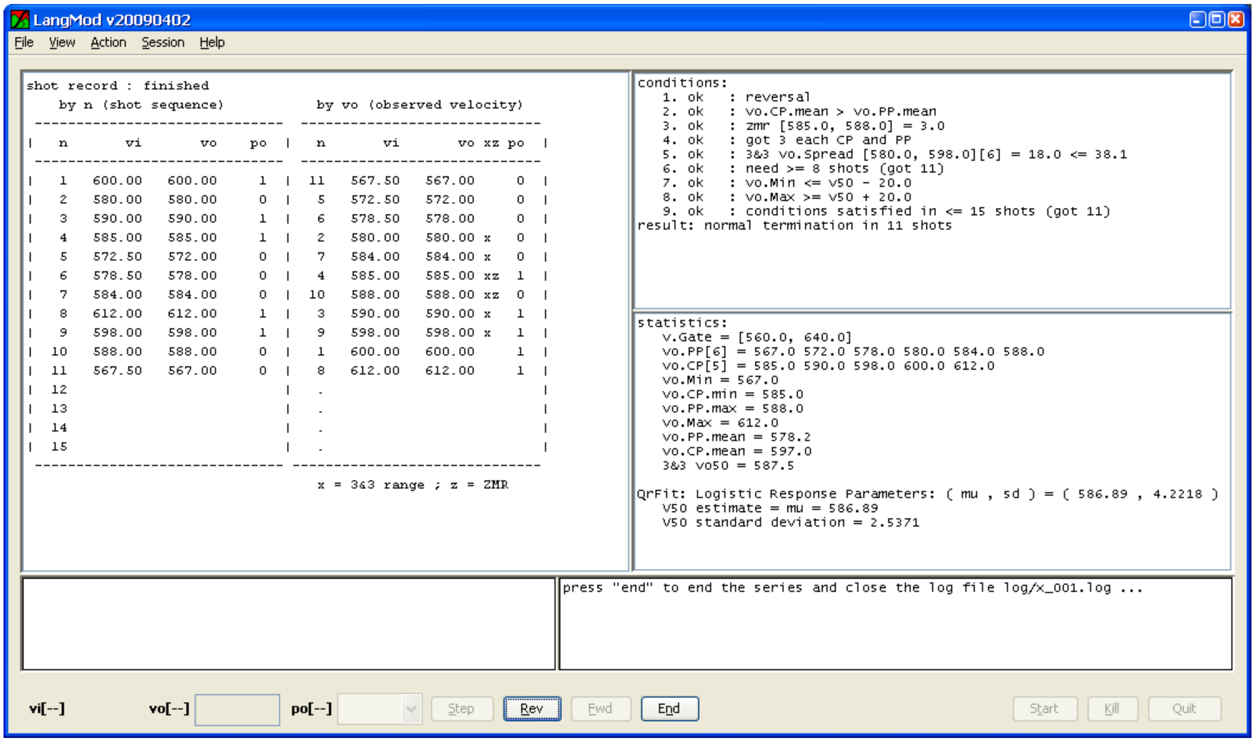

Figure 5. Experiment view – series terminated.

5.5 Experiment View – Final Summary

At this point, a summary is shown, as in figure 6. Final parameter estimates are given in the statistics area. The user may start another series or quit the program.

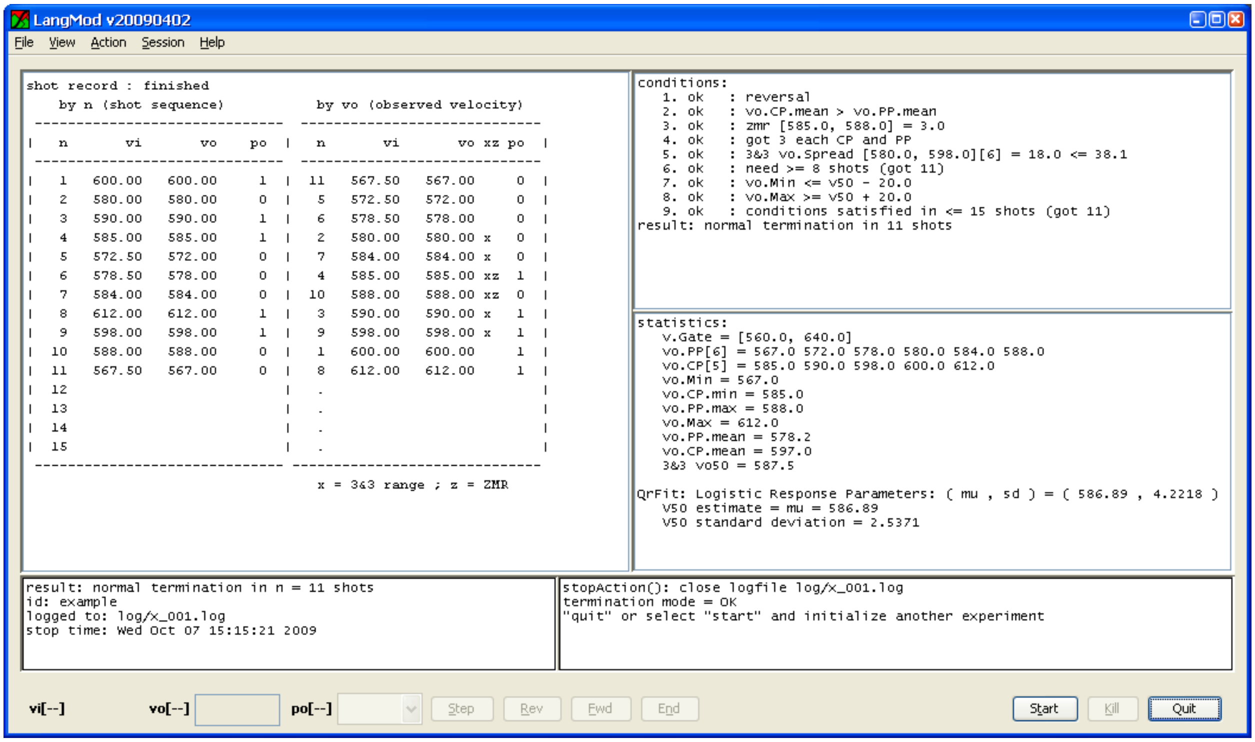

Figure 6. Experiment view – final summary.

Another feature in the shot record shows the range of velocities that covers the 3&3 (or generally, k&k) V_{50} criterion (*3*) as modified in section 9. This range is shown as an "x" next to the vo velocities. Additionally, velocities covered by the zone of mixed results (ZMR) are indicated by the "z." (See section 6 for the Langlie parameter definitions.)

5.6 LangMod Graphics

As shown in figure 7, LangMod will plot two graphs in a dedicated graph frame: (1) the velocities of PP and CP responses in shot sequence and (2) the response as a function of velocity, along with a response curve estimate when a ZMR exists. A choice of the logistic or normal function for the curve is provided in the *LangMod Graph* window under *Analysis*. When a ZMR exists, parameter estimates are given in the statistics area (mid right) of the experiment view, as in figure 6. Parameter estimates include the mean and standard deviation of the response curve as well as the V_{50} estimate and the V_{50} standard deviation for the response function selected. The parameter estimates will change with each additional shot.

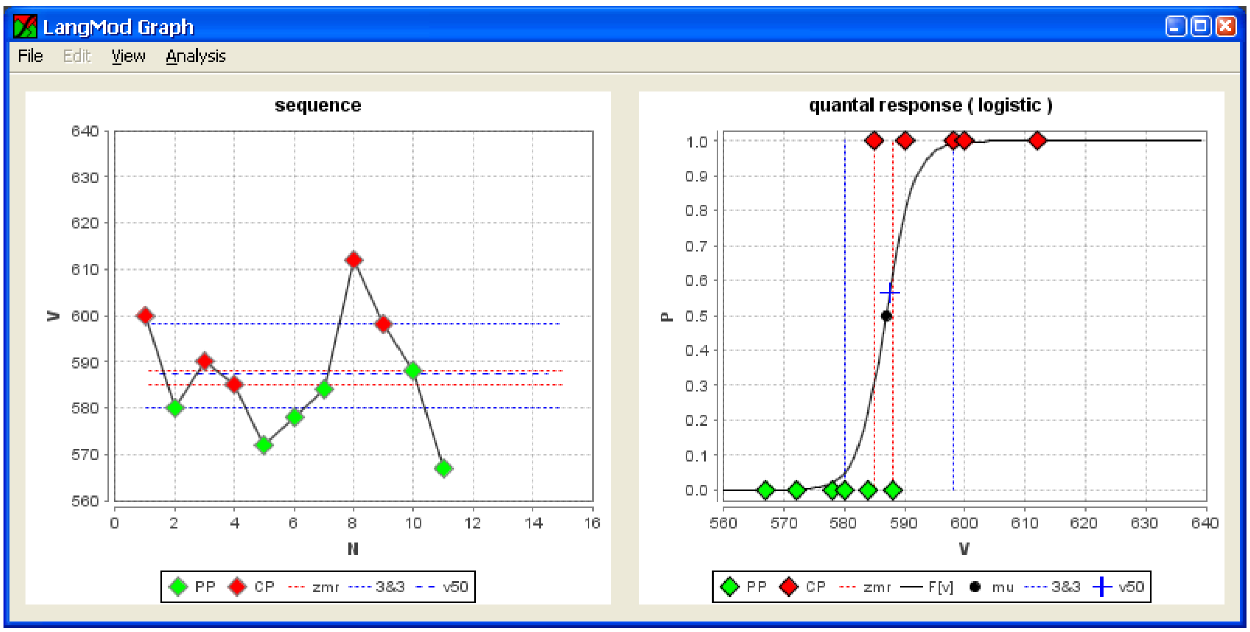

Figure 7. Graph frame.

6. Parameters

Table 1 details the basic definitions of each of the Langlie input parameters for getting V_{50} estimates. Hard targets like rolled homogenous armor generally have a tighter zone of mixed results (see definition following table 1) than softer targets like body armor. Therefore, "Nominal Values" could change based on the target and/or threat.

Table 1. Parameters.

Name	Parameter	Definition	Nominal Value
`nmin`	Minimum number of shots	The experiment will continue until this many shots are fired.	8–10
`nmax`	Maximum number of shots	The experiment will terminate after this many shots are fired.	15–18
`vmid`	Langlie gate center	The best guess of V_{50} before shooting, based on previous studies or some preliminary shots.	Interaction dependent
`rgate`	Langlie gate radius	The boundary of velocities from which to shoot. The lower gate is a value where all PPs are expected. The upper gate is a value where all CPs are expected. Shots will be in the range V_{50} ± gate radius.	250 ft/s
`gshift`	Langlie gate shift	At the start of the experiment, if there are three consecutive PPs or three consecutive CPs, the V_{50} guess may not be good, and the velocities are reaching the gates. Therefore, the gates must shift.	100 ft/s
`k`	V_{50} count	The equal number of PPs and number of CPs within the allowable velocity range used to estimate V_{50} before using statistical methods.	3
`dvk`	V_{50} gate	The allowable range of velocities for which the equal number of PPs and CPs are used as a preestimate of V_{50}.	125 ft/s[a] or 150 ft/s[b]
`bvx`	Extreme velocity basis	Base extreme velocity requirement on V_{50} or minimum CP and maximum PP.	V_{50}
`dxv`	Extreme velocity requirement	If velocities are too close to the V_{50}, select velocities this far outside the extreme velocity basis ensure a wider coverage of the velocity range (and the response curve).	100 ft/s

[a]See Zook et al. (*4*).
[b]See AVRADCOM (*5*).

The ZMR is the range of velocities in which both complete and partial penetrations can be obtained. A ZMR occurs when at least one partial penetration occurs at a higher velocity than at least one complete penetration (*6*).

A zone of mixed results is required to get estimates of the response curve slope and the standard deviation of the V_{50} estimate. This is one of the stopping rules provided in the Modified Langlie Procedure.

7. Session Manipulation – Saving and Restoring LangMod Sessions

LangMod can save an incomplete session with the *Session>Save* menu. Sessions are saved in the log directory as files with the extension `lms` for the LangMod session. This saves the parameters and the shot results. At the start of an experiment (in the parameter view), LangMod can restore a saved session with the *Session>Restore* menu. Then the user should specify a new log file name and initialize the experiment. LangMod processes the shots stored in the session file and will then accept new shots. LangMod will also restore from a killed log file. The example session and log files in the distribution correspond to the example in the next section.

8. File Details

Files are in standard Windows text format.

8.1 Initialization

The initialization file `langmod.ini` in the LangMod (or current or starting) directory holds configuration information (parameters). So, LangMod remembers initial settings (units, vmid, etc.).

```
LangMod 20090129
initialization file: jlangmod.ini
saved: Fri Jan 30 11:30:06 2009
{
	id "example_1"
	units metric
	vmid 600.0
	rgate 40.0
	gshift 20.0
	nmin 8
	nmax 15
	k 3
	dvk 38.1
	bvx v50
	dvx 20.0
	log
	ld "log"
	nosim
	rng rl
	mu 500.0
	sg 15.0
	sv 5.0
	seed 0x00000000
}
```

8.2 Session

Session (`*.lms`) files contain parameter information and shot results, as in the following example:

```
LangMod 20090129
session file:   /home/collins/langmod/log/example_1.lms
saved: Thu Jan 29 13:25:31 2009
{
	id "example_1"
	units metric
	vmid 600.0
	rgate 40.0
	gshift 20.0
	nmin 8
	nmax 15
```

```
        k 3
        dvk 38.1
        bvx v50
        dvx 20.0
        log
        ld "log"
        nosim
        rng rl
        mu 600.0
        sg 15.0
        sv 5.0
        seed 0x00000000
        n=8
        raw data:
             vo po
        600.000 1
        580.000 0
        590.000 1
        585.000 1
        572.000 0
        578.000 0
        584.000 0
        612.000 1
}
```

8.3 Logging

Log (`*.log`) files contain a text representation of the shot-by-shot session interaction, followed by session information in section 8.2 and summary information, such as the following:

```
result: normal termination in 11 shots
id: example_1
logged to: log/example_1.log
stop time: Wed Jan 29 14:08:23 2009
stopAction (end): close logfile log/example_1.log
```

So, raw shot data (velocity and penetration) can be extracted from logs and session files. For example, use the following:

```
grep -E '^[ 0-9.]+^M$' example_1.log
```

8.4 Layout

Window size can be adjusted, and the splitters between the text areas can be dragged around. LangMod remembers this layout information, which is stored in the following file:

```
mainFrame.session.xml
```

in a directory named

```
$HOME/.Langmod
```

or

```
%APPDATA%\ARL_SLAD\Langmod
```

depending on the operating system. If the GUI layout gets corrupted, delete this file and restart LangMod to reset the layout.

9. Modified Langlie Procedure Definition

The following paragraphs are edited excerpts from appendix C of Collins et al. (*2*).

The sequential firing procedure based on the Langlie method (*7, 8*) was conducted to select velocities for obtaining estimates of the V_{50} ballistic limit. Several modifications were made to obtain velocities away from the mean to better estimate the entire response curve and establish stopping rules.

1. Select lower and upper projectile velocity limits (gates) for the threat tested. The lower gate is that velocity where we would expect to consistently see partial penetration. The upper gate is that velocity where we expect to consistently see complete penetration. These gates should be set so that lower gate is at least 20 m/s lower than the lower limit of the expected zone of mixed results and the upper gate is at least 20 m/s higher than the upper limit of the expected ZMR.

2. Fire the first round at a velocity midway between these two limits.

3. If the first round results in a complete penetration, drop the velocity of the second round halfway between the first round velocity and the lower limit velocity; if the first round results in a partial penetration, raise the velocity of the second round to halfway between the first round velocity and the upper limit velocity.

4. If the first two rounds result in a reversal (one partial and one complete), fire the third round midway in velocity between the velocity of the first two rounds. If the first two rounds result in two partials, fire the third round at a velocity halfway between the second round and the upper limit. If the first two rounds result in two complete penetrations, fire the third round at a velocity halfway between the velocity of the second round and the lower limit.

5. If a reversal does not occur in three rounds, adjust the lower and upper limits as follows. If all rounds resulted in partials, raise the lower and upper limits by 20 m/s and fire the next round halfway between the last round and the new upper limit. If all rounds resulted in complete penetrations, decrease the lower and upper limits by 20 m/s and fire the next round halfway between the last round and the new lower limit.

6. Fire the succeeding rounds as follows:

    a. If the preceding PAIR of rounds resulted in a reversal, fire at a velocity midway between the two velocities.

b. If the last two rounds did not produce a reversal, look at the last four rounds. If the number of completes and partials is equal, fire the next round between the velocity of the first and last round of the group. If the last four did not produce equal numbers of partials and completes, look at the last six, eight, . . . , until the number of partials and completes is equal. Always fire at a velocity that is halfway between the first and the last round of the group examined (not necessarily the highest and lowest of the group).

c. If the conditions in 6b cannot be satisfied and the last round resulted in a complete, fire the next round at a velocity midway between the last round and the lower velocity limit; or if the last round resulted in a partial, fire at a velocity midway between the last round and the upper velocity limit.

d. Continue as in 6a and 6b for a minimum of 8 shots and a maximum of 15 (for this firing program) until the following stopping rules can be applied:

   i. Obtain a ZMR (at least one partial penetration has a higher velocity than a complete penetration). The size of the ZMR is defined as the difference in velocity between the highest partial penetration and the lowest complete penetration.

   ii. The average of the complete penetrations is larger than the average of the partial penetrations.

   iii. The spread of the tightest (smallest velocity spread among all shots) three partial penetrations and three complete penetrations is within 38 m/s (125 ft/s).

   iv. Ensure that the data set contains values approximately $\pm\Delta$ from the V_{50} that is estimated from the tightest three partial penetrations and three complete penetrations. Set $\Delta = 20$ m/s unless a wider band is required, as given in step 5. (This value does not have to be the same as the gate radius.) If velocities do not exist at these outer values, test at a velocity of $V_{50} + \Delta$ m/s and/or $V_{50} - \Delta$ m/s. Where shots permit (assuming the previous data were properly obtained with less then 10 shots), an additional shot(s) may be conducted at the following velocities to provide more balanced data:

      - between the lowest shot (the aforementioned $V_{50} - \Delta$) and the lowest complete penetration
      - between $V_{50} + \Delta$ and the highest partial penetration

Use all data to get estimates of the V_{50} using maximum likelihood estimation or generalized linear models.

10. Modified Langlie Procedure Example

An example of the Langlie procedure is shown in table 2.

Table 2. Modified Langlie procedure example.

Shot	Strategy	Velocity	?P
	1: gates	560 640	—
1	2: vmid	600 1 ----------------------	CP
2	3: avg 1, lo gate	580 0 ----------------------------------	PP
3	6a: avg 1, 2	590 1 ----------------------------	CP
4	6a: avg 2, 3	585 1 -------------------------------	CP
5	6c: avg 4, lo gate	572 0 ------------------------------------	PP
6	6a: avg 4, 5	578 0 ---------------------------------	PP
7	These are three PP and three CP. Compute the delta (spread) = 600 – 572 = 28. This is within 38 m/s, but there is no zone of mixed results. Continue testing.		—
	6b: avg 3, 6	584 0 -------------------------------	PP
8	Is there a zone of mixed results? No. Continue testing.		—
	6c: avg 7, hi gate	612 1 --------------	CP
9	Is there a zone of mixed results? No.		—
	6a: avg 7, 8	598 1------------------------	CP
10	Is there a zone of mixed results? No.		—
	6b: avg 6, 9	588 0 ---------------------------	PP
11	Is there a zone of mixed results? Yes. Is the average of the CP (597.0) greater than the average of the PP (580.4)? Yes. What is the average and spread of the tightest three PP (580, 584, 588) and three CP (585, 590, 598)? 587.5 with a spread of 18 m/s. Are there velocities at least 587.5 ± 20 m/s (567.7 and 607.5)? No/yes. Test at 567.		—
	6(d)iv	567 0 -------------------------------------	PP
	Stop testing.		—

11. References

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	ABERDEEN PROVING GROUND
1	US ARMY DEV TEST COM TEDT TMT 314 LONGS CORNER RD APG MD 21005-5055
2	US ARMY EVALUATION CTR TEAE SV P A THOMPSON N DUNN 4120 SUSQUEHANNA AVE APG MD 21005-3013
5	US ARMY ABERDEEN TEST CENTER C ANDRES B GILLICH K HACKER T HUMISTON B SMALL BLDG 400 APG MD 21005
1	US ARMY ABERDEEN TEST CENTER W BLETHEN BLDG 688 APG MD 21005
1	US ARMY ABERDEEN TEST CENTER D TEREK BLDG 691 APG MD 21005
23	DIR USARL RDRL SL J BEILFUSS J FEENEY J FRANZ M STARKS P TANENBAUM RDRL SLB A R DIBELKA G MANNIX RDRL SLB D R GROTE J EDWARDS D HISLEY T HOLDREN R KINSLER F MARSH L MOSS J POLESNE S POLYAK B SMITH E SNYDER RDRL SLB E M MAHAFFEY M PERRY RDRL SLB G P MERGLER RDRL SLB S S SNEAD RDRL SLB W L ROACH

INTENTIONALLY LEFT BLANK.