Spreadsheets Need Testing Too. Finding Billion Dollar Bugs

STARCanada
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Lawrence Livermore National Laboratory

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Eight Expensive Spreadsheet Mistakes

- Fidelity Minus Sign Mistake 1/1995 ……$2.6 Billion
- TransAlta “Clerical Error” 6/2003 ……$24 Million
- Fannie Mae “Honest” Mistake 10/2003 ……$1.3 Billion
- University of Toledo Projected Revenue 5/2004 ……..$2.4 Million
- Red Envelope 3/2005 ……Shares plunge 28%
- Think and Do 3/2005 ……number of bachelor degrees 11% instead of 20% in Virginia
- Kodak Restates 11/2005 severance pay error …….....$11 Million
- Westpac Profit 11/2005…….....Trading halted for early release of profits

Eight of the Worst Spreadsheet Blunders, Thomas Wailgum, August 17, 2007
http://www.cio.com/article/131500/Eight_of_the_Worst_Spreadsheet_Blunders?page=1&taxonomyId=3000

Fidelity INVESTMENTS Minus Sign Mistake - $2.6 B

- Copy from master spreadsheet to one for accountant
- Accountant omitted a minus sign from a $1.3B capital loss, so it was counted as a capital gain.
- The net error was the dividend estimate was $2.6B too high
- Lesson Learned – Differentiate gain and losses, have independent check

TransAlta™ Clerical Error $24M

- Canadian company bought more power than needed from US company at a higher price.
- Cut and paste error not caught on spreadsheet during sort and ranking of bids.
- Lesson learned: Have another employee double check documentation

FannieMae Honest Mistake $1.3B

- Mistakes made in implementation of new accounting standard.
- Lesson learned: Have a financial peer review the documentation.

Projected Revenue - $2.4M

- Typo in formula overstated the funds available for use.
- Lesson learned: Extra scrutiny and review. User training.

28% Share Value Drop

- Overestimation of gross margins led to forth quarter over projection of profits.
- Number misrecorded in cell.
- Lesson learned: More quality control

Number degrees 11% instead of 20%

- Researchers at Virginia Tech cut and paste error causing the number of population over 25 with bachelors degrees in a region to be lower than actual.
- Lesson learned: Have another employee check the work

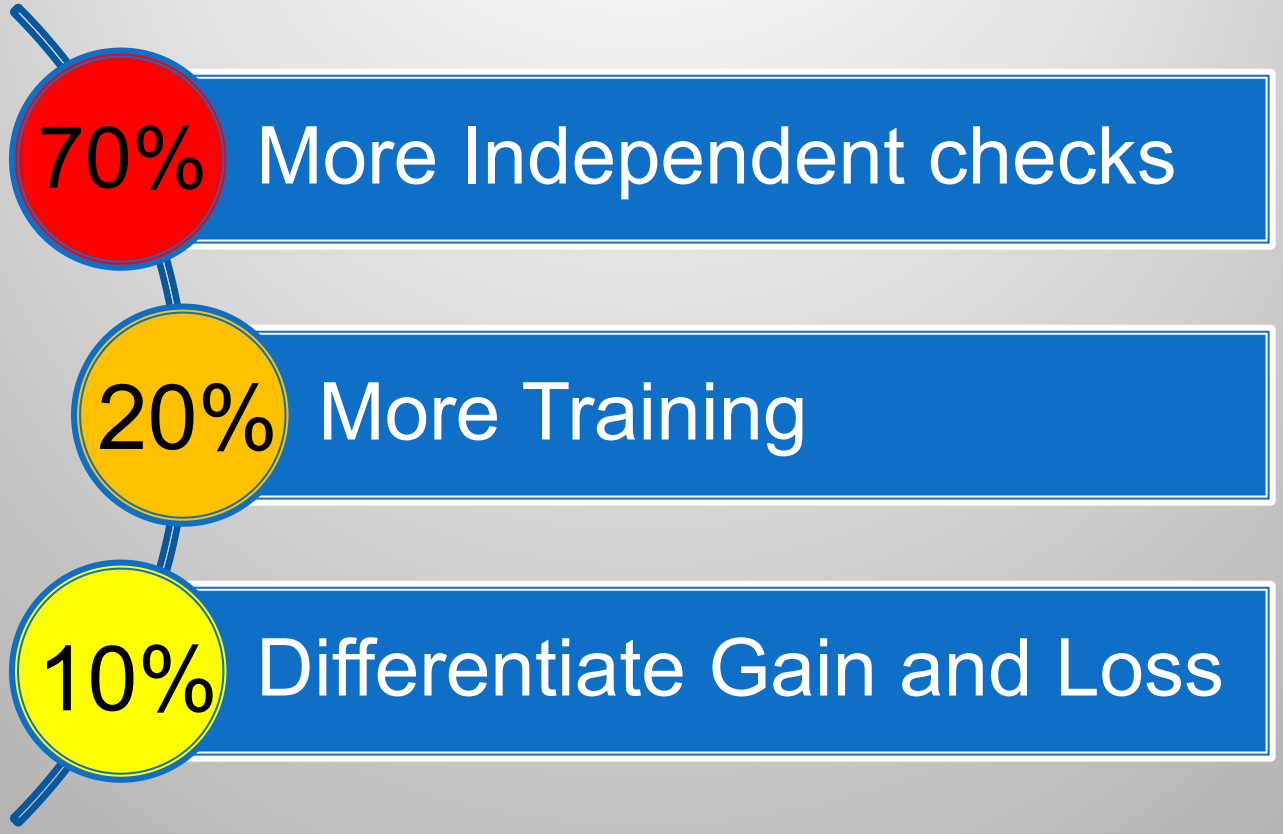
Kodak Restates Severance - $11M

- Over stated severance pay due. Error was on one employee's severance pay, there were too many zeros.
- Lesson learned: Lack of data quality control

Westpac Bank Profit Trading Suspended

- Released the results of next quarter profits early by putting them into an existing spreadsheet and then hiding them by making the cell fill black.
- Lesson learned: Additional training.

Lessons Learned Summary



Based on: Eight of the Worst Spreadsheet Blunders, Thomas Wailgum, August 17, 2007
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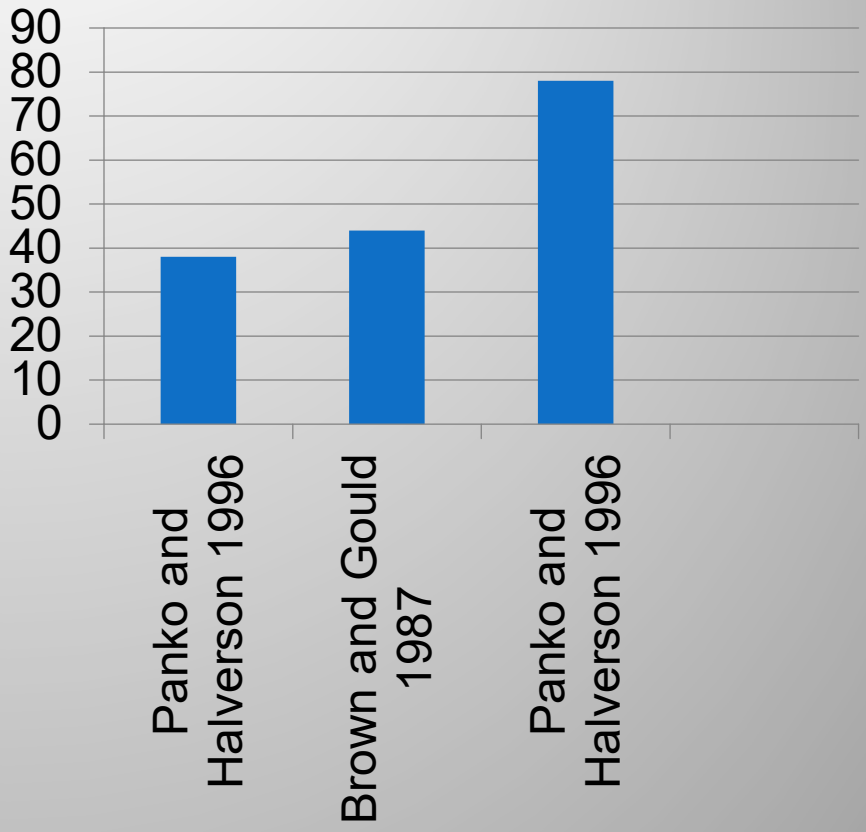
How Many Spreadsheets?

- Microsoft Office: 450 Million Desktops
- Financial Models
- Scientific Models
- Software Test Tools

Erroneous Spreadsheets

- 44% of “finished” spreadsheets still had errors [Brown and Gould 1987]
- other such studies reported errors in 38% to 77% of spreadsheets at a similar stage [Panko and Halverson 1996]



Spreadsheet Error Density

Figure 3: Audits of Real-World Spreadsheets

Authors	Year	Number of SSs Audited	Average Size (Cells)	Percent of SSs with Errors	Cell Error Rate	Comment
Hicks	1995	1	3,856	100%	1.2%	One omission error would have caused an error of more than a billion dollars.
Coopers & Lybrand	1997	23	More than 150 rows	91%		Off by at least 5%. This amount could indicate
KPMG	1998	22		91%		Only significant errors that could affect decisions.
Lukasic	1998	2	2,270 & 7,027	100%	2.2%, 2.5%	In Model 2, the investment's value was overstated by 16%. Quite serious.
Butler	2000	7		86%	0.4%**	Only errors large enough to require additional tax payments.**
Clermont, Hanin, & Mittermeier	2002	3		100%	1.3%, 6.7%, 0.1%	Computed on the basis of non-empty cells.
Interview I*	2003	~36 / yr		100%		Approximately 5% had *extremely* serious errors.
Interview II*	2003	~36 / yr		100%		Approximately 5% had *extremely* serious errors.
Lawrence and Lee	2004	30	2,182 unique formulas	100%	6.9%	30 most financially significant SSs audited by Mercer Finance & Risk Consulting in previous year.
Total		**88**		**94%**	**5.2%**	

Raymond R. Panko, University of Hawai'i

Imperative Software Error Rates

Application Domain	Number Projects	Error Range (Errors/KESLOC)	Normative Error Rate (Errors/KESLOC)	Notes
Automation	55	2 to 8	5	Factory automation
Banking	30	3 to 10	6	Loan processing, ATM
Command & Control	45	0.5 to 5	1	Command centers
Data Processing	35	2 to 14	8	DB-intensive systems
Environment/Tools	75	5 to 12	8	CASE, compilers, etc.
Military -All	125	0.2 to 3	< 1.0	See subcategories
§ Airborne	40	0.2 to 1.3	0.5	Embedded sensors
§ Ground	52	0.5 to 4	0.8	Combat center
§ Missile	15	0.3 to 1.5	0.5	GNC system
§ Space	18	0.2 to 0.8	0.4	Attitude control system
Scientific	35	0.9 to 5	2	Seismic processing
Telecommunications	50	3 to 12	6	Digital switches
Test	35	3 to 15	7	Test equipment, devices
Trainers/Simulations	25	2 to 11	6	Virtual reality simulator
Web Business	65	4 to 18	11	Client/server sites
Other	25	2 to 15	7	All others

5
6
1
8
8
< 1.0
0.5
0.8
0.5
0.4
2
6
7
6
11
7
4.613333

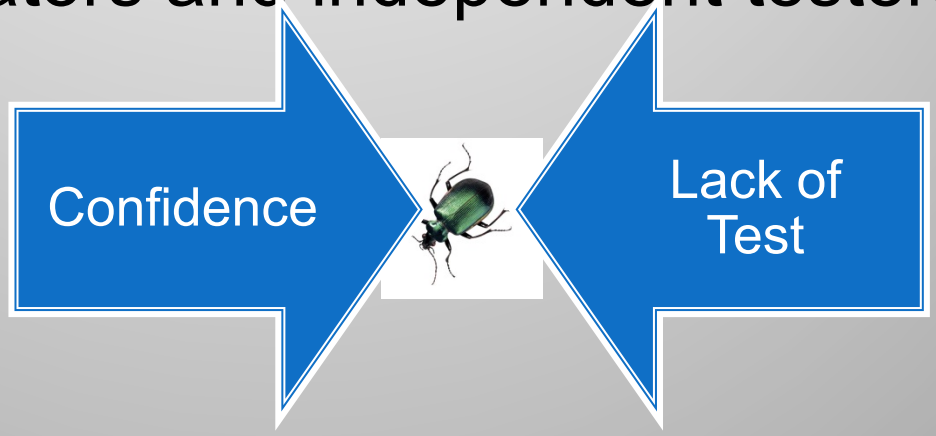
Donald Reifer, “Industry Software Cost, Quality, and Productivity Benchmarks”, DoD Software Tech News, July 2004

Comparison Spreadsheet to Software Error Rates

- Spreadsheets – average audited 5.2% error rate
- Software – 4.6 per KSLOC or .46% error rate
- So spreadsheets 10 times more likely to have errors than software.

Reason For Errors

- The unwarranted confidence creators of spreadsheets seem to have in the reliability of those spreadsheets [Wilcox et al. 1997]
- Testing by creators and independent testers is not common.

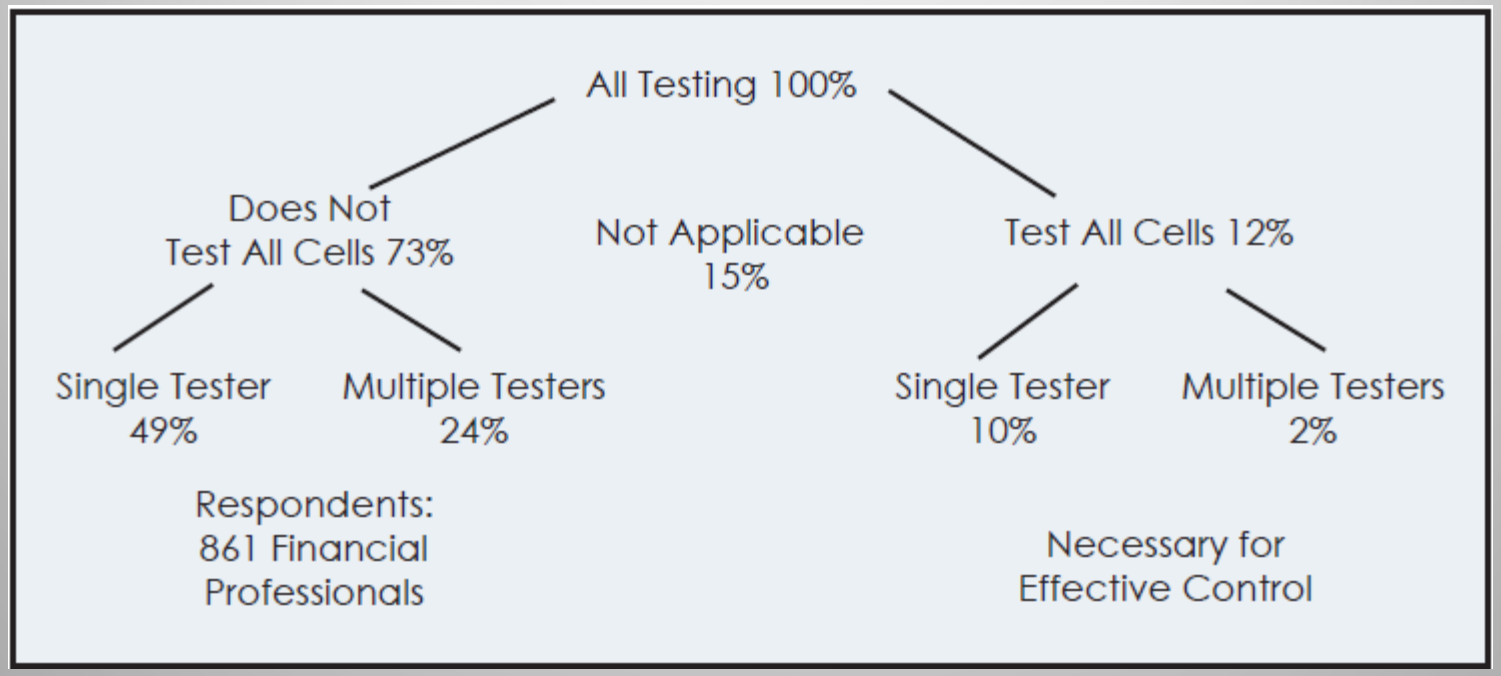


Most Companies Do Not Test Spreadsheets

Almost None	24%
Under 10%	20%
11% to 25%	12%
Over 25%	17%
Nearly All	16%
Not Applicable	11%
Total	100%
Respondents	862

Panko, Raymond R. (2005, July 7/8), "Sarbanes–Oxley: What about All the Spreadsheets? Controlling for Errors and Fraud in Financial Reporting," *EuSpRIG 2005*, University of Greenwich, London, UK. European Spreadsheet Research Information Group. http://www.eusprig.org.

Independent Spreadsheet Testing Not Commonplace



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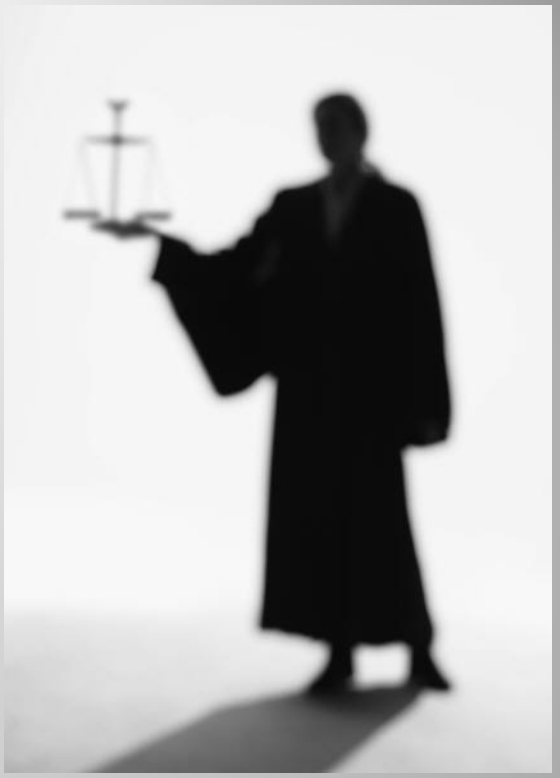
Sarbanes-Oxley Act (SOX)

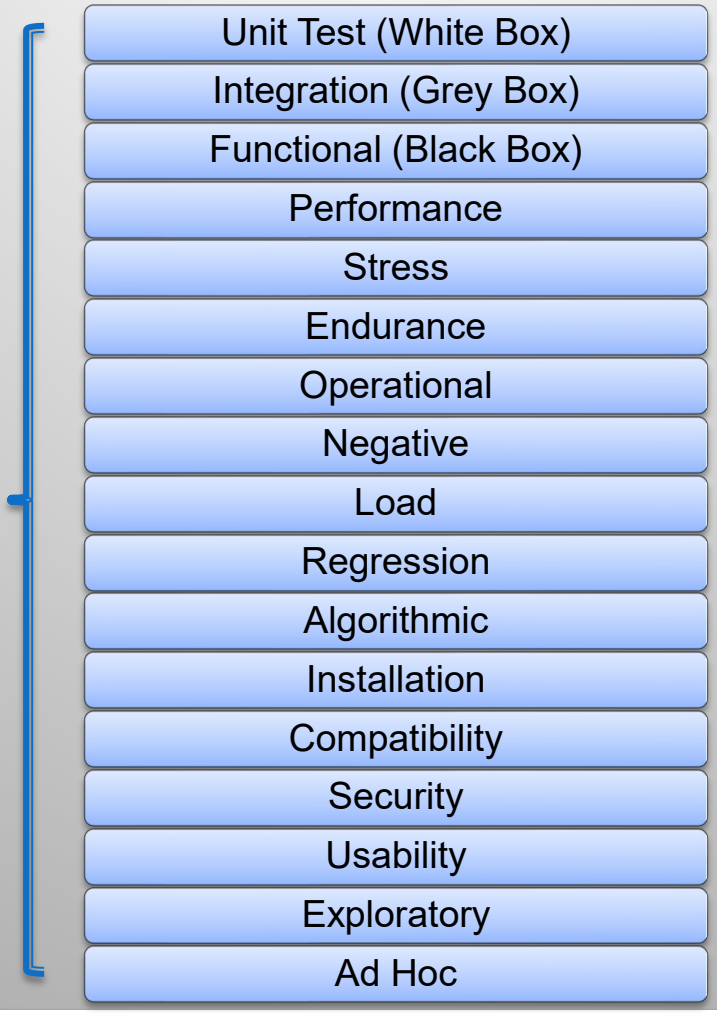


- US Federal law enacted in July 30, 2002
- Named after Paul Sarbanes (D-Md) and Michael G. Oxley (R-Oh)
- Largely adopted in Canada but less prescriptive

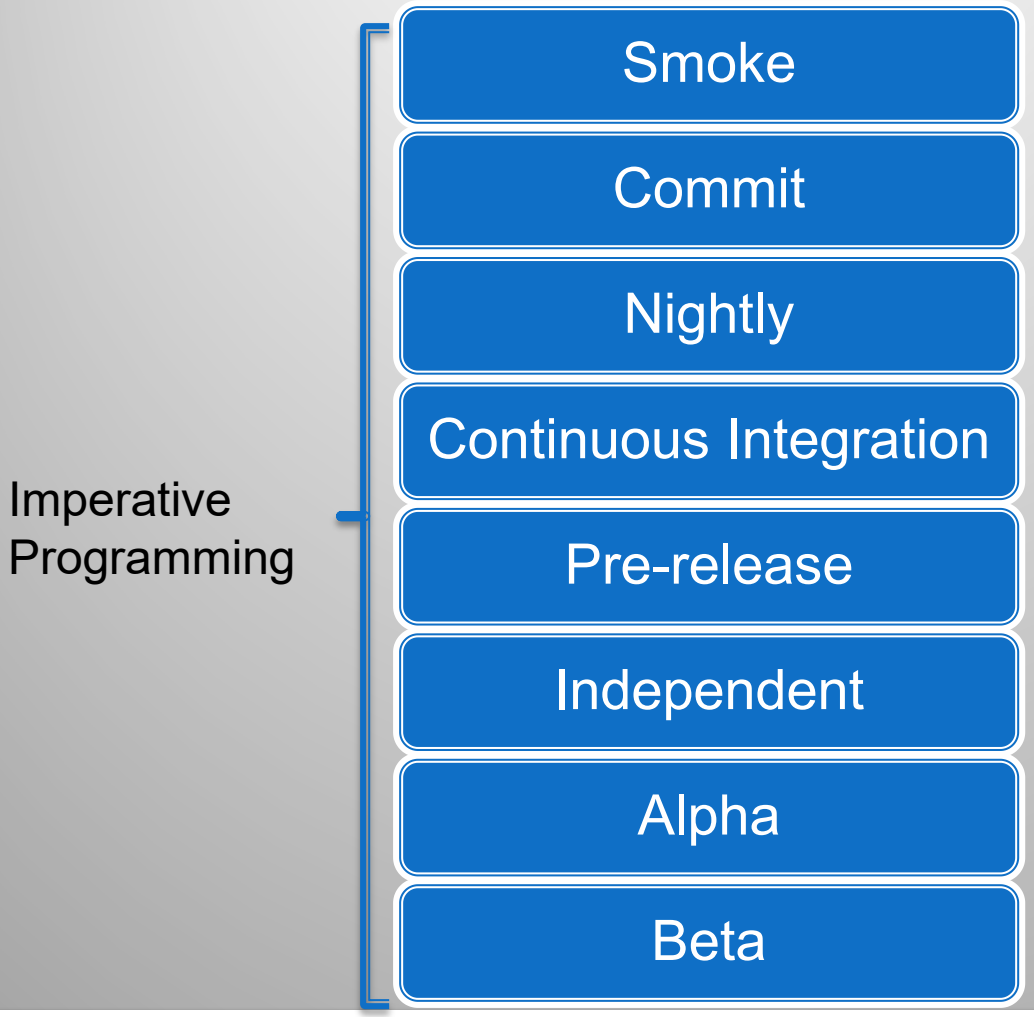
- Top management must now individually certify the accuracy of financial information.

Lots of Imperative Programming Testing Techniques

Imperative Programming

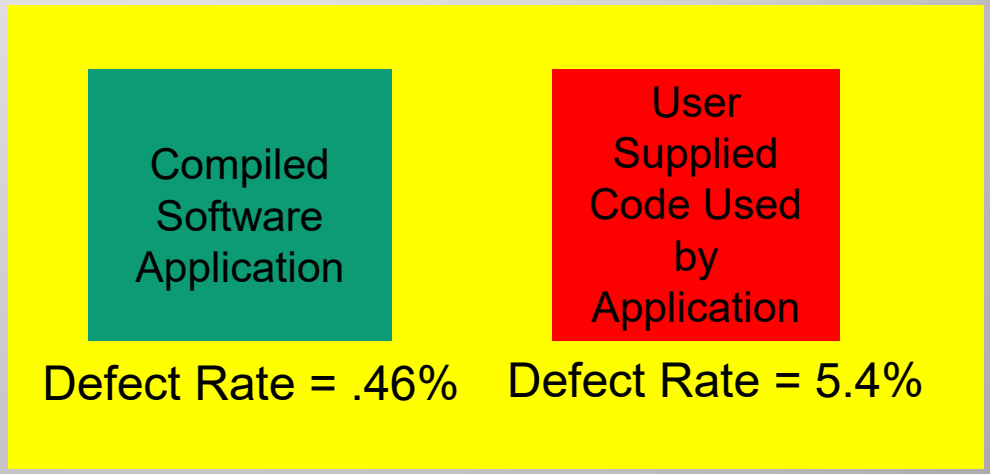


Lots of Progress on When to Test



Quality of Second Order Software Matters:

- Spreadsheets
- R (Statistical Modeler)
- Aspen
- LabView
- MATLAB
- Mathmatica
- Python Steering

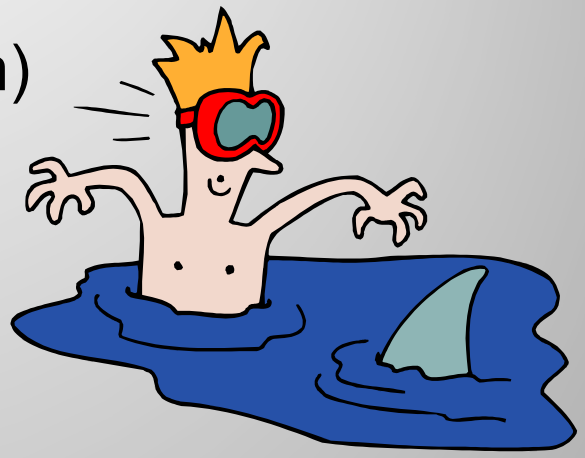


Differences Between Spreadsheets and Software

- Evaluation Order
- Most data references statically resolved
- No loops (ignoring macros)
- Incremental visual feedback
- Automatic recalculation
- User base not skilled in programming and testing

Testing Spreadsheet Risk

- Oracle for calculations
  - Check another source (validation)
  - Can be calculated in parallel
- Test has bugs
- Test Coverage
- Spreadsheet requirements scarce
- Adds Time



Spreadsheet Self Tests

B24=MAX(B5:B12)

B25 =IF(B24<=B23, “Yes”, “No”)

	A	B	C	D	E	F	G
1	**Choi Construction Company**						
2	**Payroll for week ending: 3/15/XX**						
3							
4		**Payrate**	**Regular hours**	**Overtime hours**	**Regular pay**	**Overtime pay**	**Payroll totals**
5	Adams	8.90	40	3	356.00	40.05	396.05
6	Baker	12.55	35	0	502.00	0.00	502.00
7	Carlton	9.60	40	2	384.00	38.80	422.80
8	Daniels	10.20	35	0	408.00	0.00	408.00
9	Englert	9.60	40	5	384.00	72.00	456.00
10	Franklin	11.55	40	2	462.00	34.65	496.65
11	Griffin	10.80	35	0	432.00	0.00	432.00
12	Hartford	9.90	40	9	396.00	133.65	529.65
13							
14	Totals:		305	21	$ 3,324.00	$ 319.15	$ 3,643.15
15							
16	**Audit module**						
17	**Counts:**		8	5			
18							
19	**Payroll column total:**						$ 3,643.15
20	**Sum: Regular pay + Overtime pay:**						3,643.15
21	**Match?**						Yes
22							
23	**Maximums allowed:**	$ 14.00	40.00	10.00	$ 560.00		
24	**Maximims found:**	$ 12.55	40.00	9.00	$ 502.00		
25	**Values acceptable?**	Yes	Yes	Yes	Yes		

Ferret Out Spreadsheet Errors, Mark Simon 2004, Journal of Accountancy

Parallel Copy Technique

Exhibit 1

	A	B	C	D	E	F	G
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25	Values acceptable?	Yes	Yes	Yes	Yes		
26							
27							
28	(Signature)						
29	I have examined this spreadsheet and						
30	vouch for its accuracy and completeness.						

Payroll Computations | Formulas

Exhibit 1

	A	B	C	D	E	F	G
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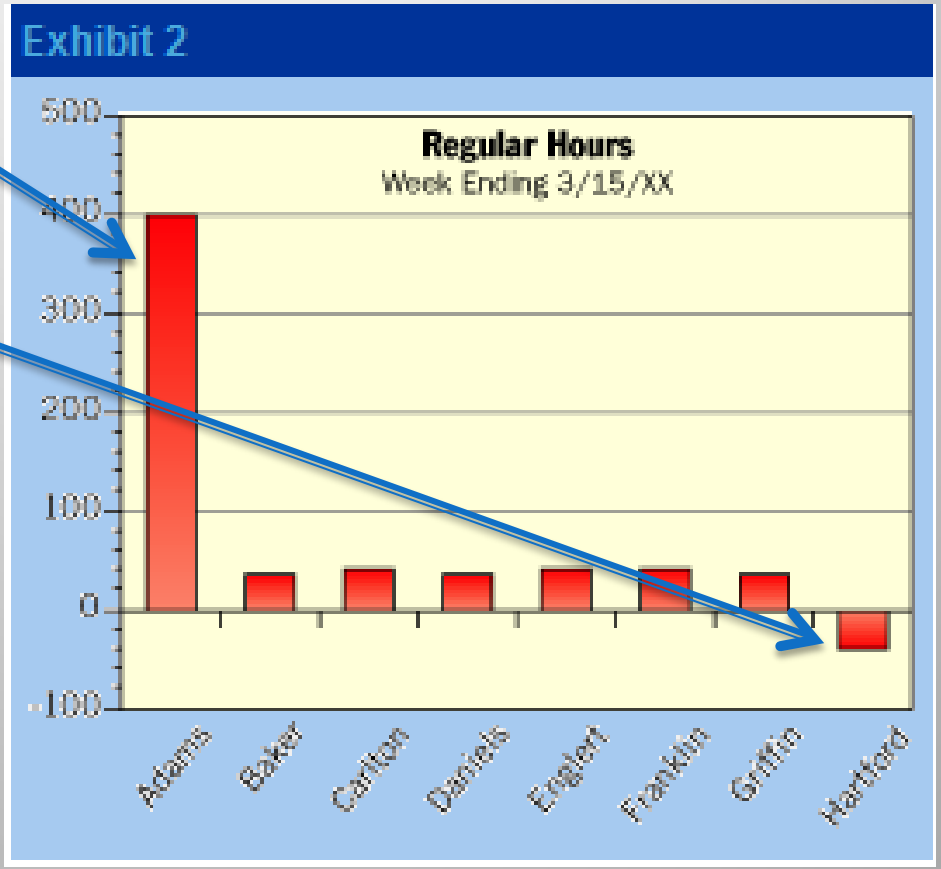
Payroll Computations | Formulas

Ferret Out Spreadsheet Errors, Mark Simon 2004, Journal of Accountancy

Plot Values, Check for Patterns

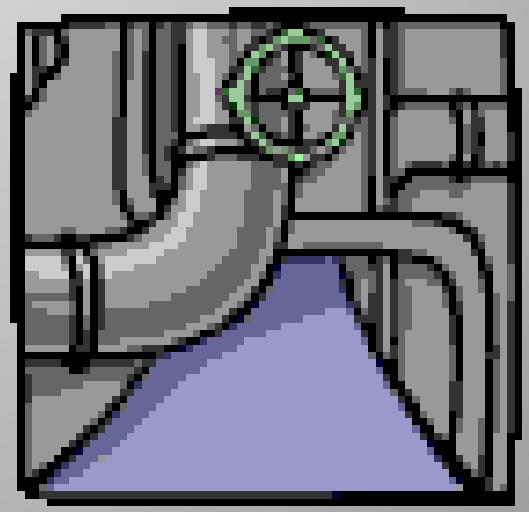
- Too many zeros
- Sign flip

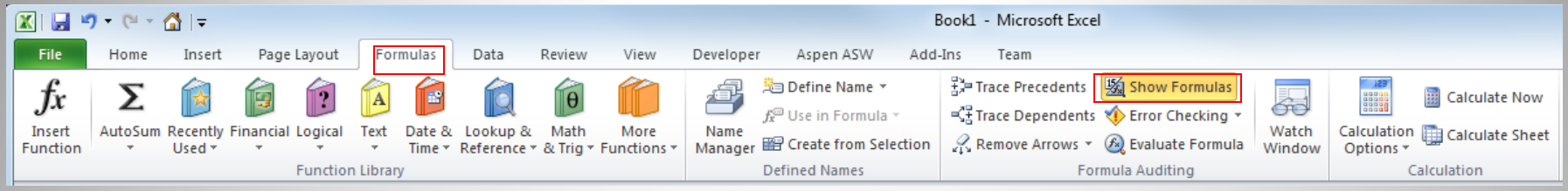


Ferret Out Spreadsheet Errors, Mark Simon 2004, Journal of Accountancy

Sensitivity Analysis

- Manipulate inputs
- Predict how other cells should change
- Check that they change as expected
- Example
  - Pay Rate goes up
  - Total pay goes up





Formula View

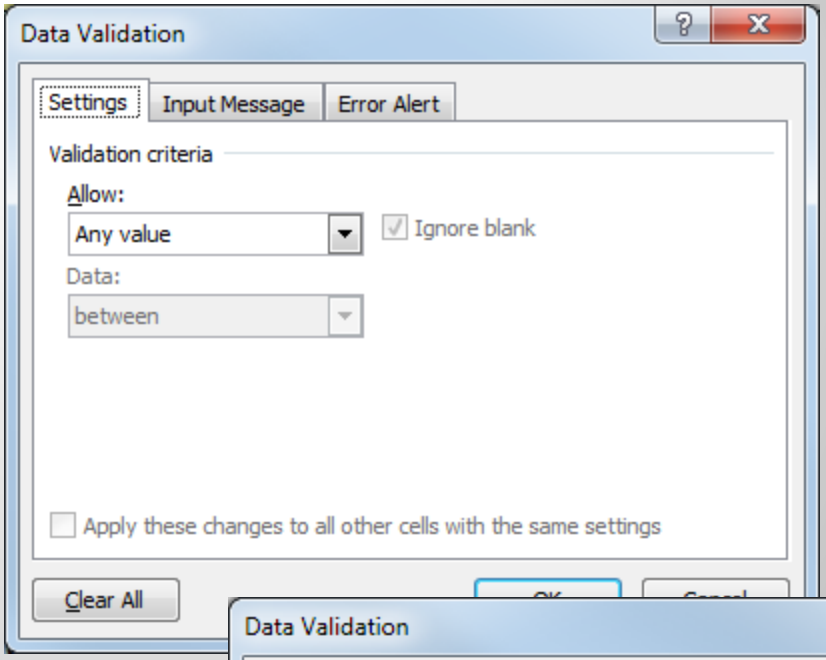
- Tools/Options/ View/check formulas or CTRL~
- Not filled down
- Constant

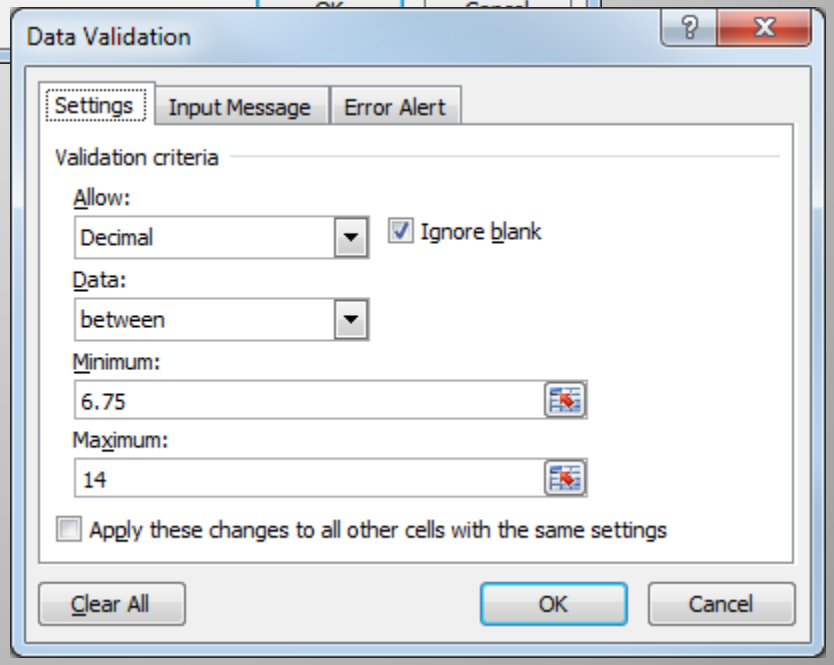
Regular pay	Overtime pay	Payroll totals
=B5*C5	=B5*1.5*D5	=E5+F5
=B6*40	=B6*1.5*D6	=E6+F6
=B7*40	38.8	=E7+F7
=B8*40	=B8*1.5*D8	=E8+F8
=B9*40	=B9*1.5*D9	=E9+F9
=B10*40	=B10*1.5*D10	=E10+F10
=B11*40	=B11*1.5*D11	=E11+F11
=B12*40	=B12*1.5*D12	=E12+F12
=SUM(E5:E12)	=SUM(F5:F12)	=SUM(G5:G12)

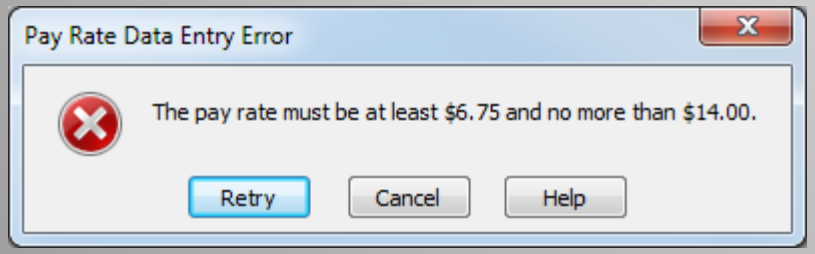
Ferret Out Spreadsheet Errors, Mark Simon 2004, Journal of Accountancy

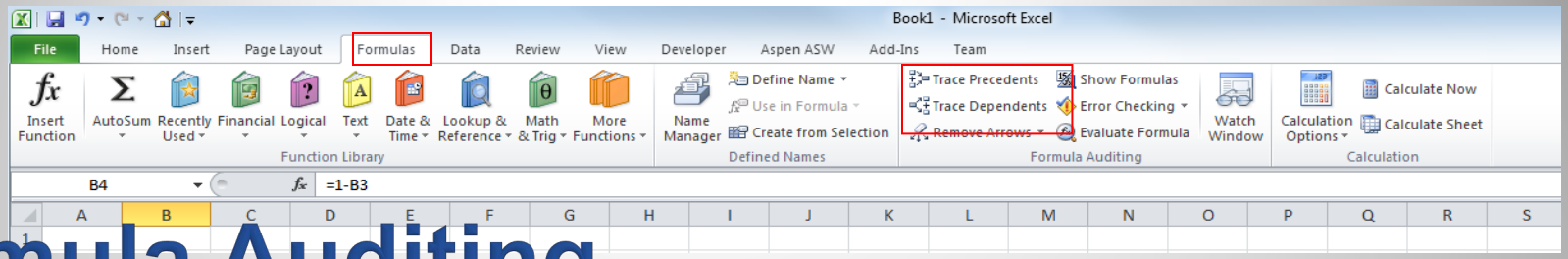
Data Validation

- Select cells
- Data/Data Validation
- Put $5 in cell B5









Formula Auditing

- Trace Precedents
- Trace Dependents

Choi Construction Company

Payroll for week ending: 3/15/XX

	Payrate	Regular hours	Overtime hours	Regular pay	Overtime pay	Payroll totals
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Audit module						
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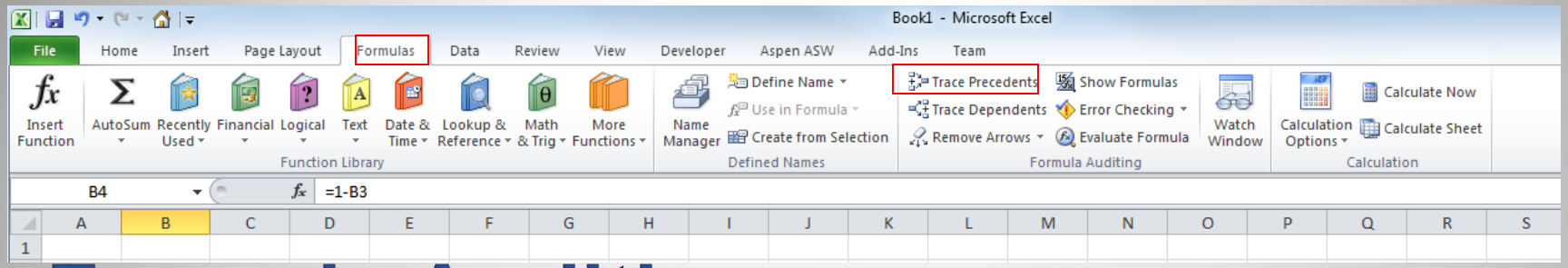

Formula Auditing

- Multiple selection of precedents
- Inconsistent dot patterns show errors

Choi Construction Company

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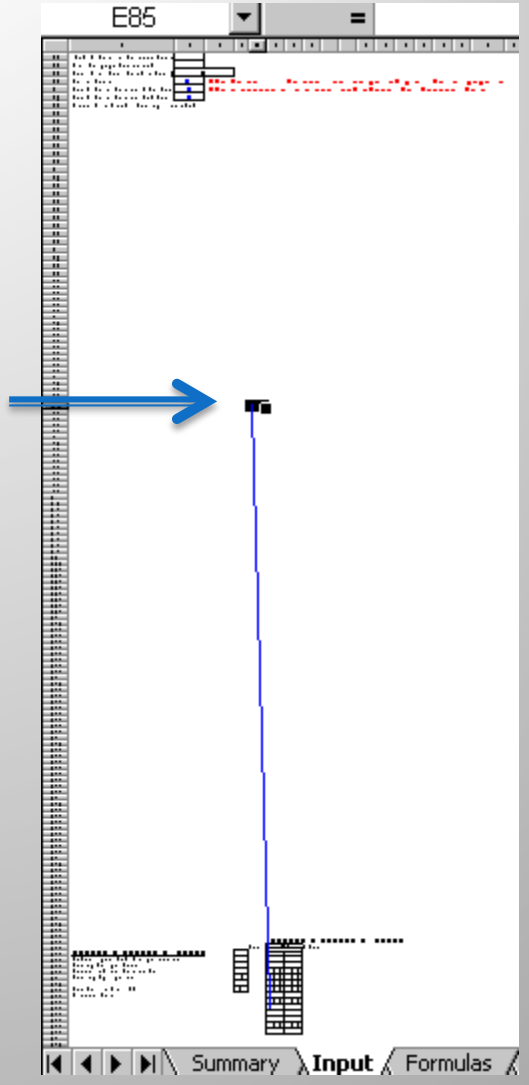
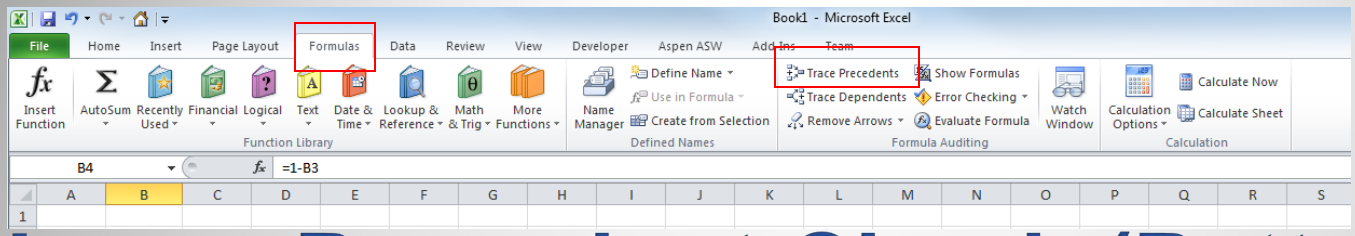
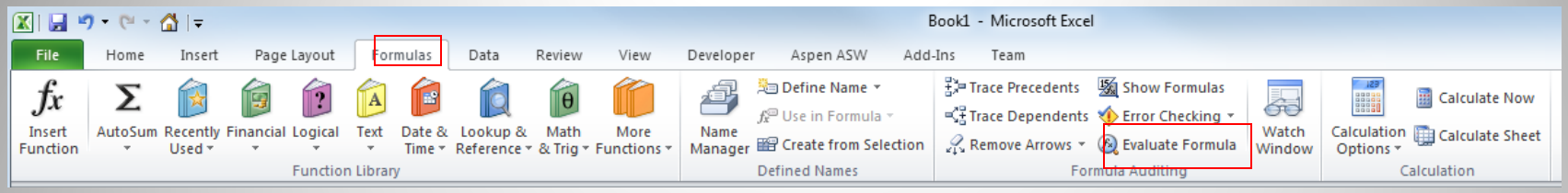
Formula Auditing

Formula references a blank cell in sparse area

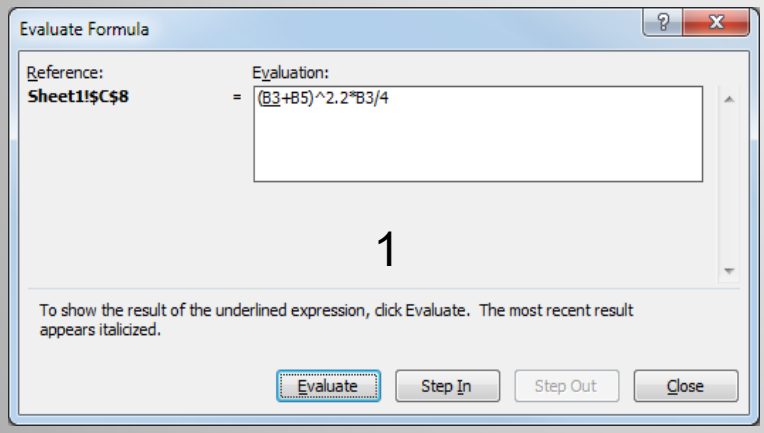


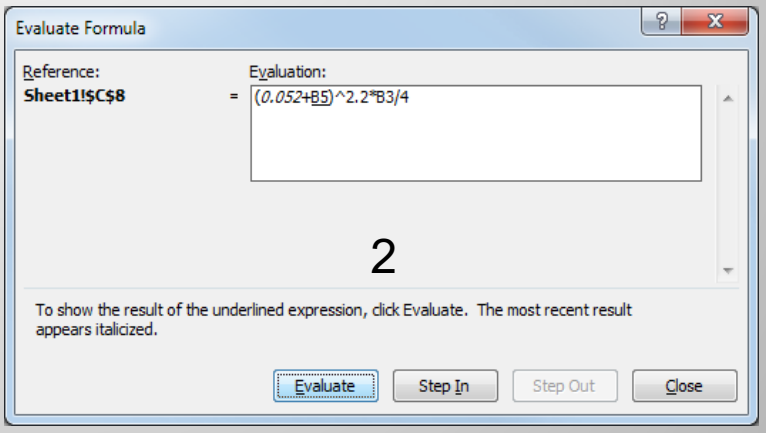


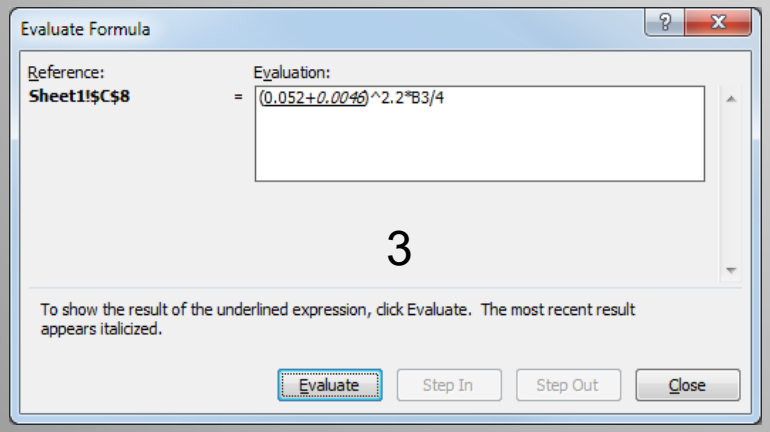
Large Precedent Check (Patterns)

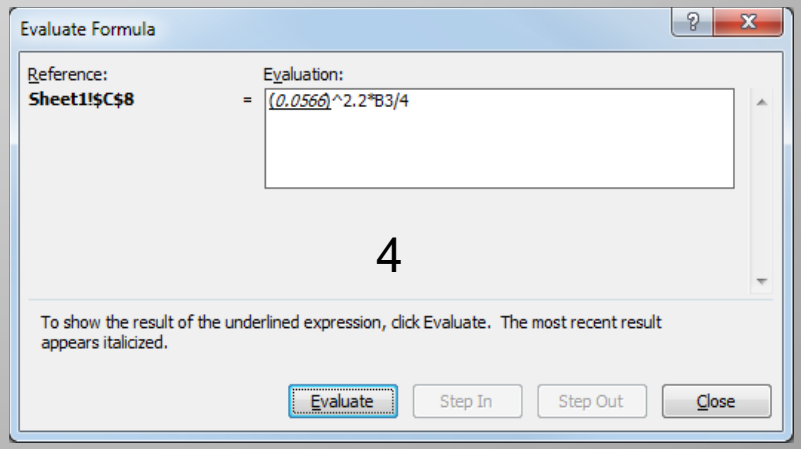


Evaluate Formula

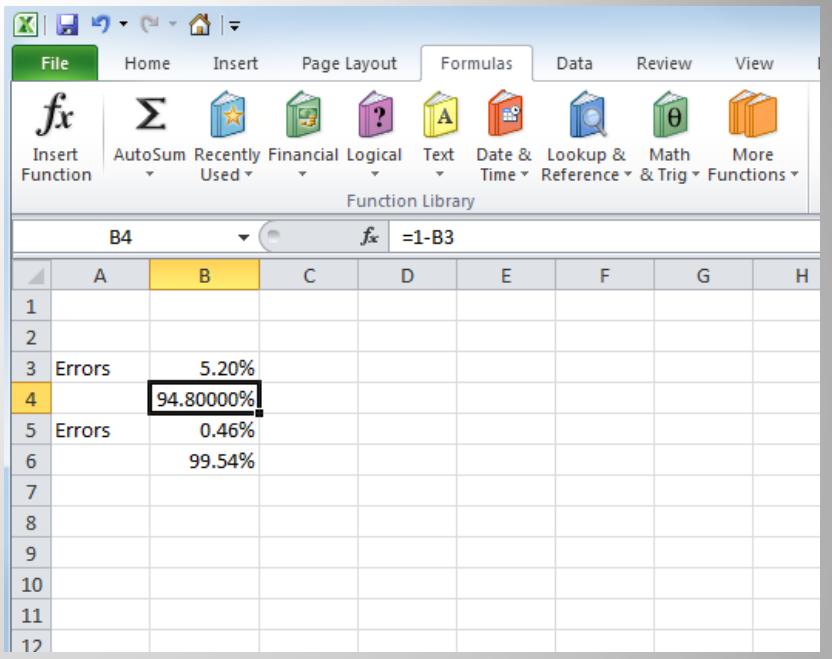








Static Error Checks



Start every function with the equal sign (=)

Match all open and close parentheses

Use a colon to indicate a range

Enter all required arguments

Enter the correct type of arguments

Nest no more than 64 functions

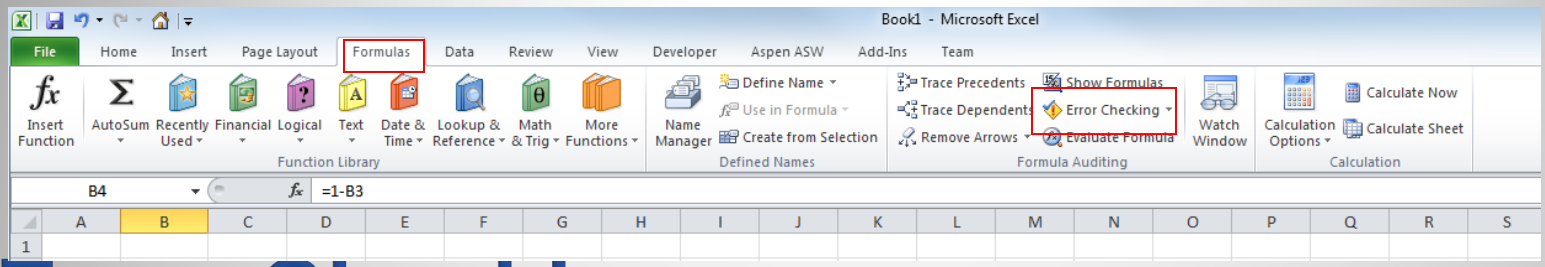
Enclose other sheet names in single quotation marks

Place an exclamation point (!) after a worksheet name when you refer to it in a formula

Include the path to external workbooks

Enter numbers without formatting

Avoid dividing by zero



Error Checking (Formula/Error Checking)

- Cells containing formulas that result in an error
- Inconsistent calculated column formula in tables
- Cells containing years represented as 2 digits
- Numbers formatted as text or preceded by an apostrophe
- Formulas inconsistent with other formulas in the region
- Formulas which omit cells in a region
- Unlocked cells containing formulas (Review/Unprotect)
- Formulas referring to empty cells
- Data entered in a table is invalid

Accountability

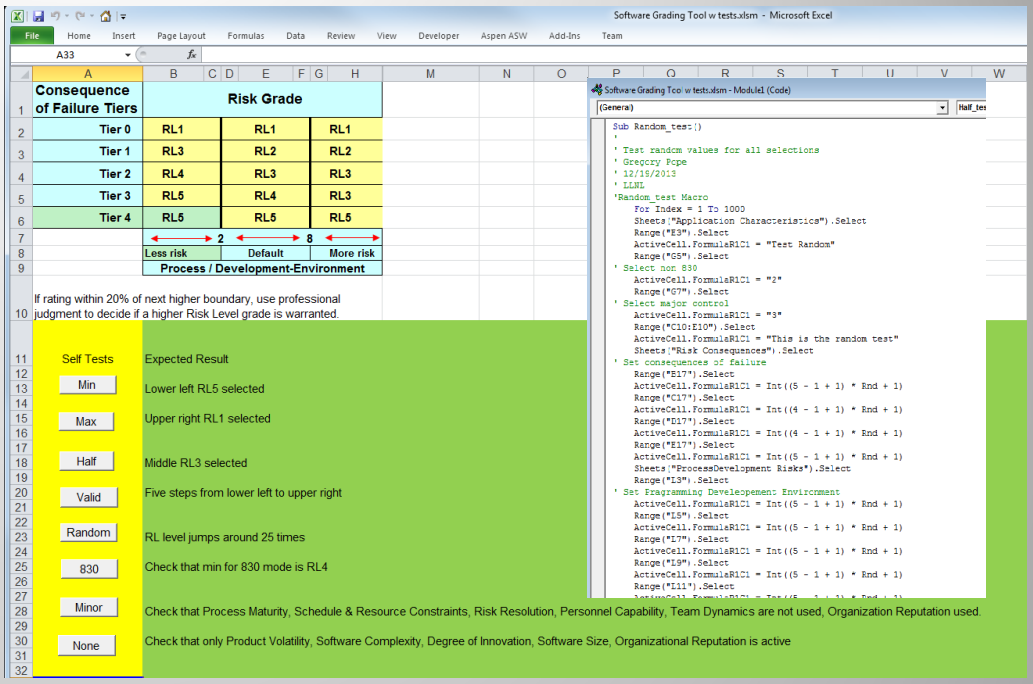
_____

(Signature)

I have examined this spreadsheet and vouch for its accuracy and completeness.

Using VB Macros to Test Spreadsheet

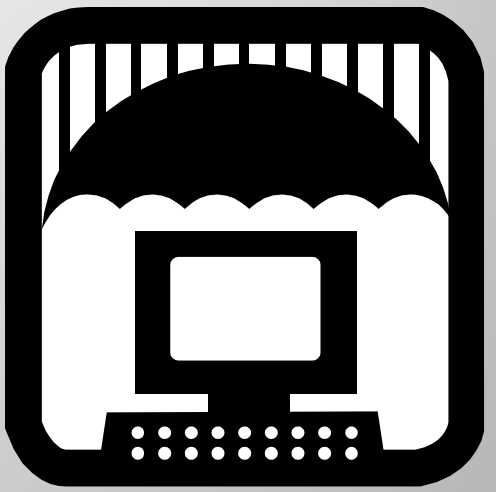
- Read and write cells
- Manipulate objects
- Boundary tests
- Random tests
- Tests stay with spreadsheet
- Example



Example sheet available at

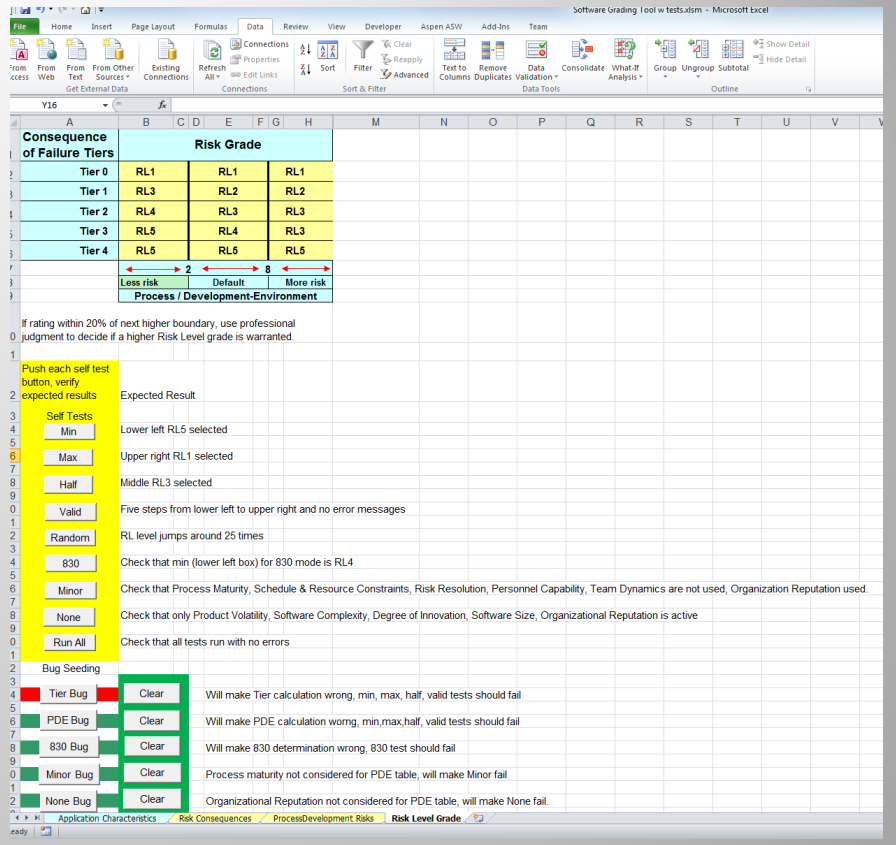
Test Coverage

- Tests should cover each function
- Boundary tests
  - Minimum +- 1
  - Maximum +-1
  - Half Scale
  - Valid Range
- Stress
  - Very large or small numbers
  - Invalid values (negative, mixed type, etc.)
- Negative (if possible)
- Random



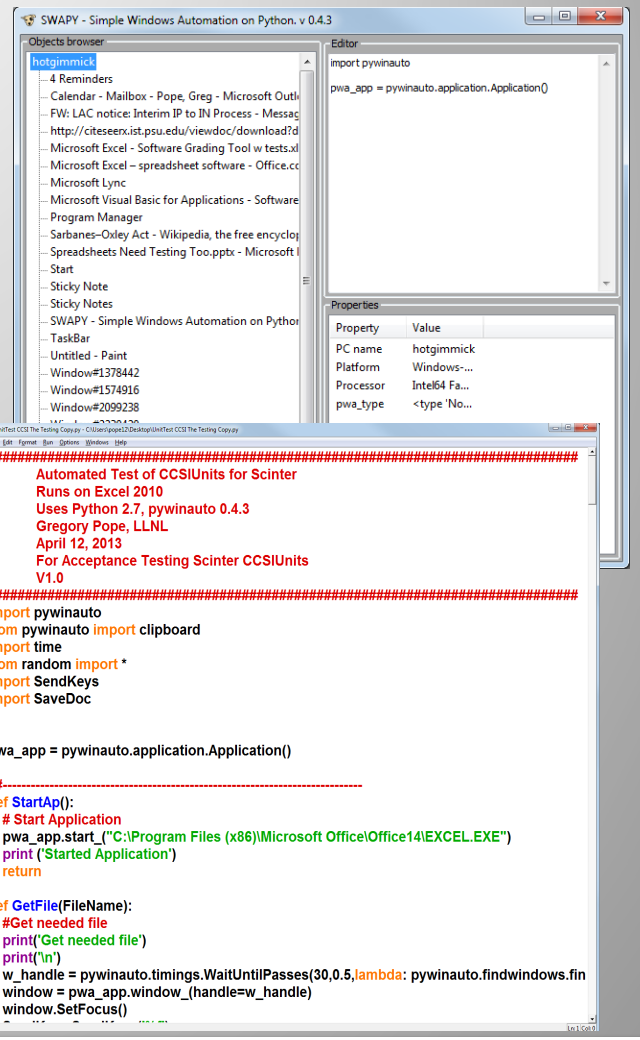
Testing Tests

- Error seed spreadsheet
  - Add +1 or -1 to answer
  - Flip sign
  - Change cell reference
- Run Tests
- Error should be detected
- Tests should fail
- Seeding/Clearing automated to prevent errors
- Indicator that error is in spreadsheet



Using Pywinauto and SWAPY

- Independent of Spreadsheet
- Windows native application
- Combined with Ghost Mouse
- SWAPY reads window objects
- Include pywinauto to python
- Example



Conclusion

- There is much known about how to prevent and detect spreadsheet errors.
- There is much known about how to test software
- The two knowledge bases have yet to merge
- We do not do a good job of testing spreadsheets
- Let us merge these areas starting today, eh?

Further Reading: *Spreadsheet Check and Control 47 key practices to detect and prevent errors*, Patrick O'Beirne