Technology
Assessment
Group

The Economic Payback of 3D Mice for CAD Design Engineers

Research Findings

Abstract

Technology Assessment Group (TAG), an independent product consulting firm specializing in product evaluation and productivity measurement, conducted this research to assess the economic impact of 3D mouse use by CAD design engineers.

User interface research by GE, IBM, and the University of Toronto suggests that substantial productivity gains should result from using well-integrated 6-degree-of-freedom (6DoF) devices for complex 3D applications such as 3D CAD.

This resulting report incorporates market data and independent research to provide a framework in which companies can estimate their economic results.

Key Findings

- **More than 84%** of CAD design engineers report a **noticeable or significant improvement** in their product designs and their ability to detect design problems as a result of using 3D mice.
- The average productivity gain reported by CAD users while using 3D mice is **21%**.
- The payback period for 3D mice is very short, typically **less than one month**.

1. INTRODUCTION

Delivering high-quality, defect-free products to the marketplace faster than the competition is central to any company's success. Both factors—quality and time to market—are critical. Companies can quickly rise—and fall—based on their performance.

Examples of this abound in the business news. For instance:

- Automobile companies are racing to deliver next-generation fuel-efficient cars in response to changed customer economy requirements and government emissions regulations.
  - Reuters reports that "as the race to bring a mass-market, rechargeable electric vehicle to the market heats up, GM executives have said the Volt is crucial to the largest U.S. automaker's efforts to snag the environmental technology crown from Japanese rival Toyota Motor Corp."
- Cell phone companies are scrambling to deliver new offerings to lure customers.
  - Motorola, the category leader in 2006 with its hot Razr product, failed to deliver compelling encores and has slipped to third place in 2008.
- Airplane manufacturers are pushing to deliver new airplanes that will constitute a substantial percentage of their future revenues. Getting to market a few months faster than the competition can make the difference between winning or losing billion-dollar orders.

In the product development chain, one key element to delivering high-quality, defect-free products quickly to the market is the performance of CAD design engineers. If they can improve their product designs, catch problem areas earlier, and do all this in less time, they can contribute to improving their companies' market performance.

Fundamental user interface research by GE Research, IBM, the University of Toronto, and others has documented the performance improvements resulting from user interface devices that enable the CAD design engineer to navigate 3D objects intuitively and to work with both hands simultaneously.

3D mice are user interface devices that provide both intuitive navigation of 3D models and the ability to work with two hands simultaneously. CAD design engineers and companies who have adopted 3D mice for their product design work have reported impressive performance gains.

But no careful quantitative research has been done to determine just how much difference these 3D mice make. And because 3D mice represent a company investment, it's important to understand the economic results, which companies can use to assess the appropriateness for their organization.

Technology Assessment Group (TAG) designed the following research to help answer these questions:

- A 14-question survey was created to collect responses from 190 existing 3D mice users. This survey was fielded by MarketLab, an independent market research group, in May 2008. The survey asked users about their experience with 3D mice with regard to:
  - Perceived improvements in product design and early defect detection
  - Productivity gains (how much faster they were in performing their work)
  - Length of time it took them to become comfortable and productive with 3D mice
  - Amount of time they spent using their 3D CAD applications

This report presents the results from this research, as well as the underlying user interface research that explains the reasons for the results.

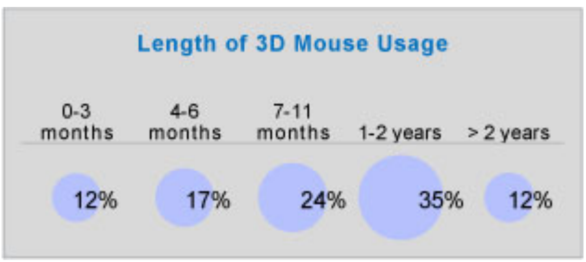
The report then addresses these fundamental management questions:

- What is the economic payback of investing in 3D mice for CAD design engineers?
- How can we determine the economic payback for our company?

2. USER FINDINGS

One hundred and ninety CAD design engineers who use 3Dconnexion 3D mice were surveyed in the U.S. They worked in companies with fewer than 10 CAD design engineers up to companies with more than 500 CAD design engineers.

These design engineers most commonly used familiar 3D CAD applications such as CATIA, Inventor, NX, Pro/ENGINEER, and SolidWorks. They represent the full range of 3D mice experience, from less than three months to more than two years. Of these design engineers, 53% used their 3D mouse for less than one year, and 88% used it for less than two years, with the breakout as shown below.

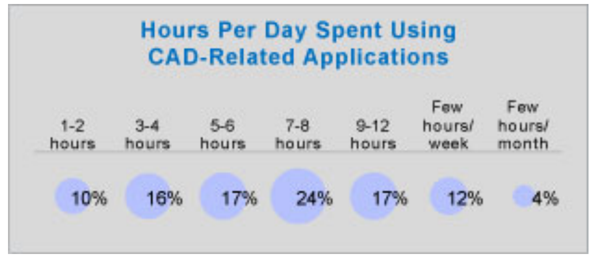


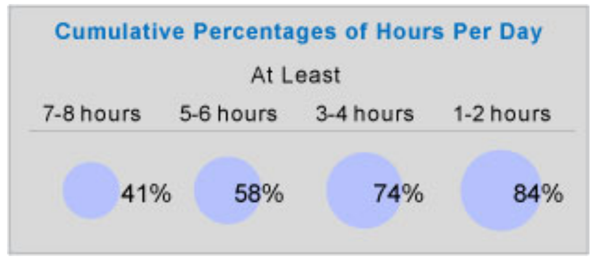
Note that for the sake of brevity in this report, percentages are presented with no decimal part. As a result, presented percentages will sometimes vary ±1% due to rounding.

2.1 Job Characteristics

CAD design engineers are different from casual computer users in that they use job-specific CAD applications many hours a day to perform their work functions.

Accordingly, 74% reported that they spend *at least* three hours a day using their CAD applications. Fully 41% spend *at least* seven hours a day. The following diagrams show the distribution of usage by group and cumulatively.





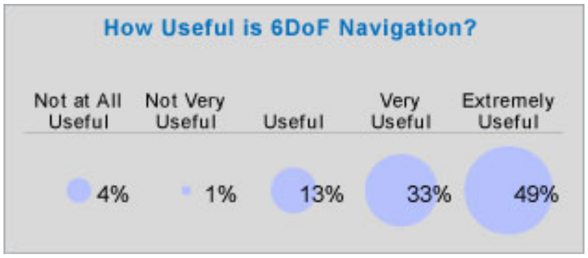
2.2 CAD Applications and 3D Mice

As stated earlier, corporate and academic research has shown that two key 3D mouse factors significantly improve the performance of people using intensive 3D applications:

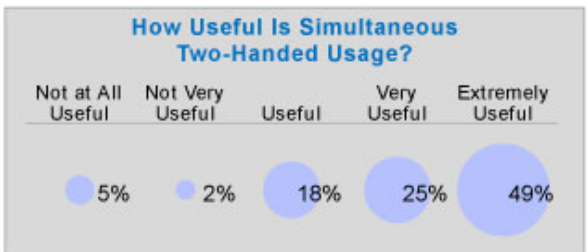
- 6DoF devices for quickly orienting 3D objects or views
- Devices that enable working with both hands simultaneously (for example, a 3D mouse in one hand and a traditional 2D mouse in the other hand)

The survey wanted to determine whether 3D mouse users experienced these two factors in their work and whether they thought these factors enabled them to produce higher-quality designs, detect errors better, and create designs faster.

Of these users, 83% reported (on a five-point scale) that the 3D mouse's 6DoF navigation was "very useful" or "extremely useful," and nearly half (49%) found it "extremely useful." Virtually all users (95%) found this feature "useful" or better. The detailed response percentages are shown below.



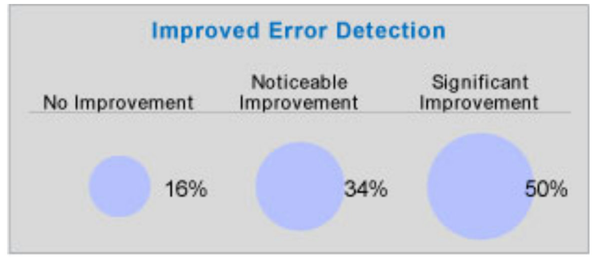
Concerning working simultaneously with both hands, 75% found the 3D mouse's enabling of two-handedness "very useful" or "extremely useful," and again, nearly half (49%) found it "extremely useful." Virtually all (93%) found this feature "useful" or better. The detailed response percentages are shown below.



How then did these factors affect the product design process? The Introduction described high-quality, defect-free products as being key to a company's success; can 3D mice actually improve design quality and reduce errors?

According to the surveyed users, a 3D mouse enabled them to much more easily rotate, inspect, and explore their designs. As a result:

- 85% saw a "noticeable" or "significant" improvement in their product designs
- 84% thought that they could "noticeably" or "significantly" improve their detection of errors



These are very high percentages, indicating that companies adopting 3D mice for their CAD design engineers should confidently expect similar results.

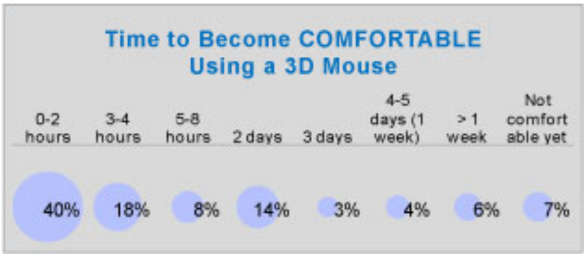
And what about design speed—the time it takes design engineers to create their design? Are they faster (more productive) using a 3D mouse? Improving CAD designer productivity will directly contribute to faster time to market, which can have an enormous impact on a product's success in the marketplace.

CAD designers reported that they were, on average, 21% more productive using 3D mouse than they were without a 3D mouse. More than 86% of the users reported productivity increases, ranging from under 10% to over 50%. The following chart details the responses.

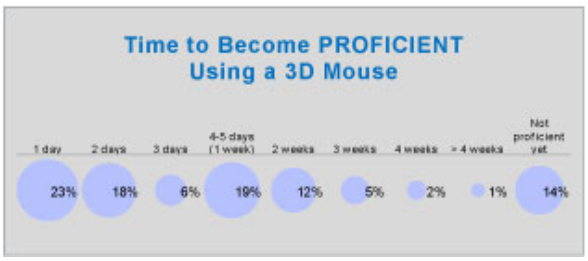
What about the learning curve for using 3D mice? If it takes three months to become comfortable with a 3D mouse and another three months to become productive, are these productivity gains worth the learning curve?

In order for users to embrace a new way of working, it's critical that they can quickly become "comfortable" with the new style. If they find the new approach awkward or cumbersome, they'll abandon it, even if it might pay dividends downstream.

With 3D mice, more than half the users (58%) were comfortable within the first four hours, and the vast majority (80%) were comfortable within two days.

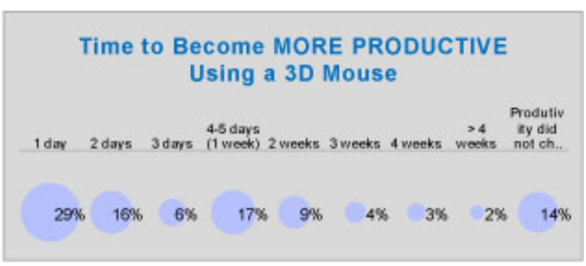


Next, how long does it take for users of 3D mice to feel not only comfortable but "proficient"? According to the survey, 3D mouse users move quickly from feeling comfortable to feeling proficient: 66% felt proficient within the first week, and 78% within two weeks.



How quickly does a 3D mouse user become more productive? This is the ultimate goal of any changed work style.

Users reported that nearly half (45%) were more productive within two days, and 68% were more productive within the first week of using a 3D mouse.



3. UNDERLYING USER INTERFACE RESEARCH

It is important to understand the fundamental user interface concepts that underlie these productivity improvements. This provides an understanding both for CAD design engineers who experience these improvements as well as non-CAD professionals who might wonder why 3D mice would make such a difference.

This section first explains how a CAD design engineer's computer use varies from casual computer user. It then addresses the unique user interface demands presented by 3D CAD applications. The user interface bandwidth concept is introduced along with two major UI bandwidth accelerators.

References for the research cited in this section can be found in the References section at the end of this report.

3.1 CAD Design Engineers vs. Casual Computer Users

CAD design engineers commonly:

- Work at a core job function that depends heavily on job-specific, complex CAD applications
  - The most frequently used 3D CAD applications are CATIA, Inventor, NX, Pro/ENGINEER, and SolidWorks.
- Often spend more than half of their day using their CAD applications
- Require very high-performance computers in order to increase job productivity
- Spend between $1000 and $50,000 on application software

More than one million 3D CAD users worldwide share this profile.

In contrast, casual computer users:

- Work at a core job function that may involve using general-purpose applications (e-mail, Web access, word processing, spreadsheet, and so on) but that typically does not depend on job-specific applications
- Spend, on average, less than half of their day on a computer
- Have less need for high-performance computers
- Spend less than $1000 on application software

The table below summarizes the core differences between these two classes of computer users.

	3D CAD User	Casual User
Applications	Complex, job-specific	General-purpose
Computer Use	4–8 hours/day	0–4 hours/day
Computer Performance	High performance	Medium performance
Application Purchases	$1000 – $50,000	< $1000

These differences provide a context for examining the characteristics of 3D CAD applications and their unique user interface challenges.

3.2 Characteristics of 3D CAD Applications

3D CAD users have substantially more demanding computer working styles than casual users. Their job-specific applications typically require them to work in the following unique ways:

- More frequent navigation of the work (models, views)
- More complex (degrees-of-freedom) navigation (panning, zooming and rotating much more common)
- Dramatically more commands/minute and navigations/minute than a casual computer user
- Much greater number of frequently used commands

To illustrate, imagine a casual user reading e-mail, the most frequently used application. The user would start reading an e-mail message and perhaps scroll down vertically to finish reading it. Then they might "reply" or "forward" the message, and then select the next email to read. In this typical scenario:

- The navigation (vertical scrolling) is typically limited to one degree-of-freedom (1DoF), as is the selection of the next e-mail message to read.
- The number of commands actually used is fairly limited.
- The user input "bandwidth" requirement is quite low, for both navigation and commands.

If you were to watch this user's hands from above, the pace would be measured and slow. In contrast, the 3D CAD user's hands appear like those of a concert pianist racing through a fast passage, the right hand rapidly moving the mouse and mouse wheel while the left hand repeatedly selects keys (often Ctrl, Shift, Alt, and Esc) on the keyboard.

Based on observation of and interviews with 3D CAD users, TAG estimates that 3D CAD users issue 5 to 10 times more navigations/minute and commands/minute than casual users. This demand to "push" a large number of navigations and commands per minute is the core requirement of high-bandwidth user interfaces, as discussed in the next section.

3.3 User Interface "Bandwidth"

3D CAD application's performance can be throttled by three distinct bandwidth channels:

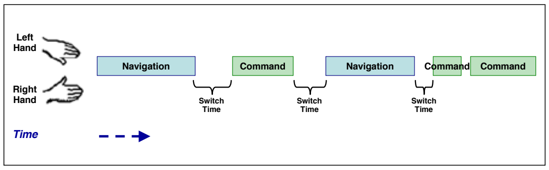
- Computer bandwidth
- Graphics bandwidth
- User Interface bandwidth

To illustrate, let's take the example of a mechanical engineer designing a new faucet using 3D CAD software such as Pro/ENGINEER or SolidWorks.

- The computation bottleneck is the ability of the software/computer to keep a 3D model up-to-date. As products become more complex, the computation requirements increase rapidly.
- The display bottleneck is the ability of the software/graphics card to render the 3D model accurately in "real time".
- The user interface bottleneck is the ability of the user to directly move the object to the desired position and then issue various commands, with the least number of interruptions and context shifts, in the shortest amount of time.

Whereas computer bandwidth and graphics bandwidth have increased at a "Moore's Law" pace, 3D CAD user interfaces have not kept up. As a result, user interface bandwidth has emerged as one of the principal bandwidth "throttles" for 3D CAD applications today.

A conceptual framework developed by academic researchers provides a useful visual representation for understanding user interface bandwidth.

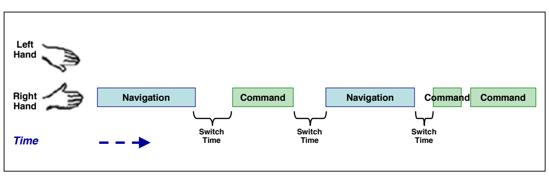


User Interface Bandwidth Framework (Source: Buxton, W., Billinghurst, M., Guiard, Y., Sellen, A., and Zhai, S. 2002)

This framework illustrates that user interfaces (today and in the near future) are driven by the activity of the right and left hands, generating both navigation and commands. User interface bandwidth is simply the time it takes to execute a series of navigations and commands to perform a particular application function.

3.4 Input Streams

The first user interface bandwidth limitation in 3D CAD applications has to do with "input streams." As just discussed, all user input is driven through the right and left hands; in reality, however, the left hand is typically doing very little except periodically invoking a "mode" key press (for example, Ctrl, Shift, or Alt). From the user interface bandwidth framework shown below, we see that the right hand (assuming a right-handed user) is doing almost all the work, essentially constituting a single input stream.



Single-Stream User Input

As summarized aptly in Zhai, Smith, and Selker (1997):

> One basic feature of the existing mainstream user interfaces is that the user communicates with the computer system via a single stream of spatial input, physically driven by a 2 degree of freedom input device, typically a mouse, and graphically displayed as a cursor. The universal cursor travels around the entire interface, switching its functions from pointing, to selection, to drawing, to scrolling, to opening and to jumping, according to what virtual devices (widgets), such as the main document/window, a menu, a scrolling bar, an icon or a hyperlink, has been acquired and engaged. Such a single stream operation, needless to say, has offered the users many advantages such as the ease of understanding and learning the interaction mechanism. The disadvantage, however, is the limited communication bandwidth (Buxton 1986) and the costs in time and cognitive effort of acquiring widgets and control points (Buxton and Myers 1986, Leganchuk, Zhai and Buxton 1996).

In observing both 3D CAD and casual computer users, TAG estimates that the 3D CAD user issues 5 to 10 times more navigations/minute and commands/minute than the casual user. When these have to proceed largely through a single stream (albeit with some use of the keyboard for buttons or modifiers), the bandwidth is severely restricted.

The first opportunity for improving user interface bandwidth is thus to increase the number of streams through which the user can drive the application.

3.5 Navigation

The second user interface bandwidth limitation is navigation. Navigation involves getting to the place of interest to perform a task. This could be scrolling to read an e-mail message, panning to a location in Photoshop, or rotating a model to view the back side of a part in CATIA.

Although navigation is a frequent activity in most applications, the nature of the navigation varies dramatically depending on the application type.

The following table provides a description of common navigation operations, together with the number of degrees of freedom (DoF) they require and some example applications.

	# DoF	Description	Common Applications
Scrolling (Vertical)	1	Moving a document up/down	E-mail, Web, Word
Scrolling (Horizontal)	1	Moving a document left/right	Excel
Panning	2	Moving a drawing simultaneously horizontally and vertically	AutoCAD, Photoshop
Zooming	1	Moving a document/model in or out	AutoCAD, Photoshop
Rotating	3	Moving a model simultaneously around any of three rotational axes	3ds Max, CATIA, Pro/ENGINEER, Maya, SolidWorks

DoF Requirements for Different Types of Navigation

These DoF numbers are additive. For example, to pan and zoom you need 2 (pan) + 1 (zoom) = 3DoF. To pan, zoom, and rotate you need 2 (pan) + 1 (zoom) + 3 (rotate around three axes) = 6DoF.

Different applications vary dramatically in their use of these various types of navigations, as shown in the following table.

Application	Scrolling (Vertical)	Scrolling (Horizontal)	Panning	Zooming	Rotating
E-mail	*****				
Word	*****	*		*	
Excel	****	***		**	
Photoshop	*	*	***	****	
CATIA and 3D CAD applications			***	*****	*****

Navigation Frequency by Application
(* = low; ** = high)***

The salient fact is that most 3D CAD applications frequently navigate using pan and zoom (3DoF) or pan, zoom, and rotate (6DoF). Accordingly, this presents another important user interface bandwidth opportunity.

"Being in the Flow"

Before turning to research regarding high-bandwidth opportunities, it's worth noting that the three bandwidth limitations break an inherently creative process called "being in the flow."

"Being in the flow" is a term used by artists, athletes and designers to describe activities where they are fully engaged and in control. Another phrase used to describe this state is "being in the zone". All of these activities involve substantial concentration and outlay of mental and/or physical energy.

For 3D CAD computer users working with complex and cognitively demanding applications, "being in the flow" translates to higher quality and faster performance. Often, however, they're distracted from their flow by user interfaces that siphon off cognitive bandwidth and require the user to slow down in order to "drive" tedious aspects of the user interface (Bederson 2002).

Significantly, one of the most common interruptions to being in the flow is a low-bandwidth user interface in which users cannot engage in their tasks as quickly as they can think.

In contrast, high-bandwidth user interfaces allow 3D CAD users to stay in the flow; we'll turn now to these bandwidth opportunities.

3.6 High-Bandwidth User Interface Opportunities

In the previous section, two significant user interface throttles were identified:

- Limited input streams
- Limited navigation

For both of these throttles, research provides approaches that can significantly increase the bandwidth.

Higher-Bandwidth Input Streams

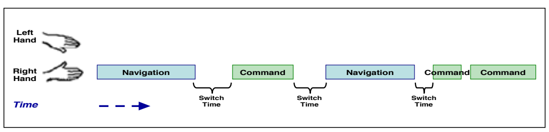
We introduced the problem of the single stream of input when we observed that 3D CAD users are trying to push 5 to 10 times more commands per minute than a casual user. Whereas a casual user might not be as greatly affected by having a single stream, the 3D CAD user has much higher bandwidth requirements.

One very promising user interface approach takes advantage of humans' ability to use both hands simultaneously in a cooperative fashion. As noted in Buxton (2002):

> A student turns a page of a book while taking notes. A driver changes gears while steering a car. A recording engineer fades out the drums while bringing in the strings.

By equipping both hands with tools to "drive" the application (typically a 3D mouse in the left hand and a standard 2D mouse in the right hand), substantial bandwidth increases can be achieved.

First, let's look again at how single-stream interfaces work today.

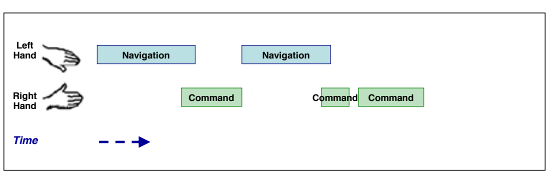


Single-Stream User Input

Note that the user incurs a switching time by going from one mode to another. The near-universal example of this is navigation and selection. The right hand first navigates to the point of interest, say on a model, using the mouse. Then the user "switches modes," whereby the mouse now becomes a selection tool to issue a command. This process repeats itself endlessly.

Also observe the lack of parallelism: the user is either navigating or selecting at one time, but not both.

A bimanual stream would change the activity profile as illustrated below.

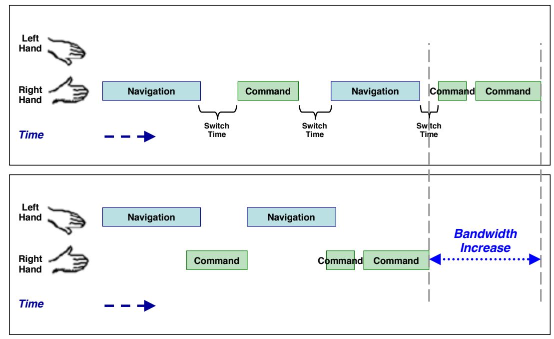


Bi-manual Input Streams

Because each hand has a tool to perform tasks, the user doesn't need to "switch" the right hand from a navigation mode to command mode and back again. Removing the unnecessary switches essentially reduces the bandwidth requirement.

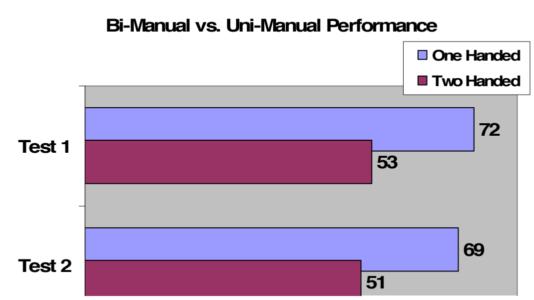
In addition, the human physiology allows for parallel activities that can be synchronized with each other, providing additional bandwidth headroom. This parallelism is depicted in the preceding illustration by the partial overlap of navigation and commands: the user can "start" the command with the right hand while the left hand is completing the navigation.

The resulting comparison of unimanual and bimanual performance is shown below.



Unimanual (top) vs. Bimanual (bottom) Bandwidth

The conceptual framework illustrated above was validated in a study conducted by IBM (Zhai 1997), in which they found that a bimanual interface (in this case, a joystick in the nondominant hand and a mouse in the dominant hand) was 1.36 times faster than using the mouse alone, in tasks involving navigation and selection.



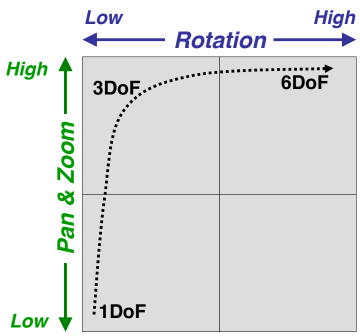
Unimanual vs. Bimanual Performance
(Source: IBM—Zhai 1997)

Furthermore, in a study conducted at the University of Toronto (1997), as the tasks became more cognitively demanding (larger, more complex models) two-handed interfaces produced an even more significant performance gain than the Zhai research.

Higher-Bandwidth Navigation

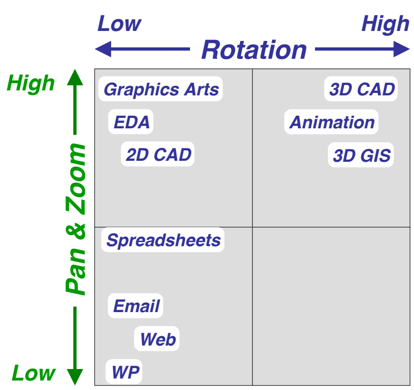
As described earlier, navigation in 3D CAD applications as compared to more traditional 2D applications is much more frequent and requires more DoFs for efficient performance.

The following diagram shows how many simultaneous DoFs are required by various types of navigation, from no rotation (scrolling) to pan and zoom and finally to pan, zoom, and rotate.



Application Navigation and DoF

3D CAD applications typically fall squarely in the 6DoF quadrant, as shown in the following diagram.



Navigation by Application Type

This introduces the potential for devices that offer more simultaneous DoFs—up to 6DoF to address applications with high zoom and pan and high rotation, which are typically 3D applications.

The following table lists common input devices and their characteristics, notably the number of simultaneous DoFs.

Device Type	Simultaneous DoFs	Rate or Positional	Example
Two-button mouse	2	Positional	Classic mouse
Wheel mouse	2+1	Positional	Microsoft IntelliMouse
Graphics tablet	2+1+1+1	Positional	Wacom Intuos
Joystick	2+1	Rate	Logitech Wingman
3D motion controller	6	Rate	3Dconnexion SpaceBall

Device Types and Characteristics

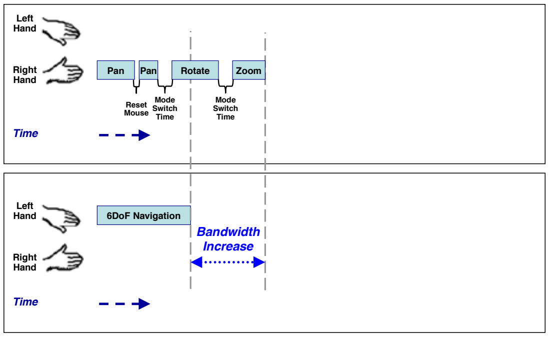
The conventional mouse offers 2DoF, being able to move along the plane of a desk. The mouse wheel separately offers 1DoF (typically for scrolling in text-based applications, and for zooming in 3D applications). Users typically do not move the mouse and spin the wheel at the same time, so a wheel mouse can be described as a 2+1DoF device.

A 6DoF device allows the user to move in one fluid movement to zoom, pan, and rotate the object to any orientation.

In contrast, the wheel mouse's 2+1DoF intrinsic capabilities require a modal DoF mapping to achieve 6DoF navigation, typically involving pressing an additional key. A common approach is as follows:

- Mode A (Ctrl key depressed) + mouse movement *pans* the model
- Mode B (Alt key depressed) + mouse movement *rotates* the model
- Mode C (no keys depressed) + mouse wheel *zooms* the model

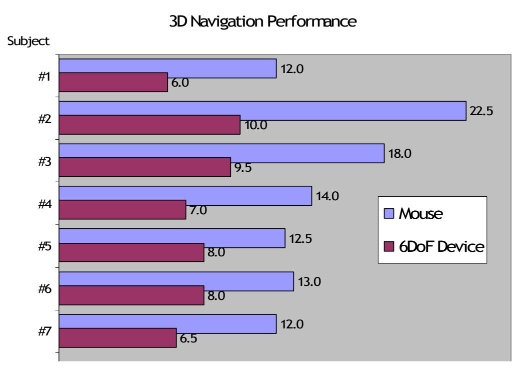
Using the UI bandwidth framework, the following comparison shows the increased bandwidth resulting from using a 6DoF device for 3D navigation.



Mouse (top) vs. 6DoF device (bottom) 3D Navigation

One of the most common activities in 3D CAD applications is the frequent precise movement of a model from one orientation to another. In a GE study of seven users (Salazar and Marteau, 2004), users had to move from one of eight possible starting points to reach a precise (+/–1°) target 3D orientation, using a classic mouse and a 6DoF device.

In the GE study, users could achieve the target 3D orientation almost twice as fast with a 6DoF device (in this case, a 3Dconnnexion 3D mouse) as compared to a standard 2D mouse, as noted in following graph.



3D Navigation Performance: Standard Mouse vs. 6DoF Device (Source: Salazar and Marteau 2004)

When using the standard mouse, users took 89% longer to perform the required 3D orientation. Moreover, all users were substantially faster when using the 6DoF device, ranging from 1.56 to 2.25 times faster, suggesting that the results would apply broadly to all users.

Rate vs. Positional Devices for Navigation

Another point worth noting is the distinction between rate devices and positional devices, and their respective strengths for navigation. The earlier table showing device types and characteristics indicates which devices are rate vs. positional. According to Zhai (1997):

> As shown in recent six degree of freedom input control studies (Zhai and Milgram 1993, Zhai, Milgram and Drascic 1993, Zhai 1995), position control is better conducted with isotonic, free moving devices, such as the mouse; and rate control is better conducted with isometric or elastic devices. The key factor to this compatibility issue is the self-centering effect in isometric or elastic devices. With self centering, rate control can be easily done. Without it, rate control requires conscious effort. Either position control or rate control can give users the ability to control all aspects of movement, including displacement, movement speed or higher order derivatives, but each mode corresponds to only one aspect directly: displacement or speed.
>
> A rate control technique that is compatible with isometric devices can be particularly suitable for navigation tasks where you need very precise movement and also very large movements (e.g. scrolling long documents, rotating a model, moving a camera) as no repetitive release-reengage problem exists as in the case of a mouse.

3.7 User Interface Research Conclusions

3D CAD computer users require much a higher user interface bandwidth in order to stay in the “flow” of their work and perform at their optimum level.

3D CAD users issue 5 to 10 times more navigations/minute and commands/minute than casual users. 6DoF navigations are common, further taxing user interface bandwidth. These points, coupled with the high percentage of time that 3D CAD users spend using their CAD applications, present significant opportunities for improving productivity by increasing user interface bandwidth.

Two user interface approaches present substantial potential for improving productivity:

- Bimanual interfaces, using a mouse in the dominant hand and a rate device in the nondominant hand **(1.36 times faster—IBM research)**
- A 6DoF device for the nondominant hand, particularly in 3D applications **(1.89 times faster—GE research)**

Moreover, these approaches should have an additive impact, further increasing the user interface bandwidth for 3D CAD users.

The survey of 3D mice CAD users and the time-measured test designed by a senior CATIA application engineer indicate that significant productivity gains can be realized by 3D CAD design engineers. Fundamental user interface research further explains the reasons for such gains.

The productivity increases reported by CAD design engineers and the productivity time measurements of CATIA users are concrete manifestations of this underlying research.

Given these impressive productivity increases, it's now time to address the larger economic question: what is the economic payback of equipping CAD design engineers with 3D mice?

4. ECONOMIC PAYBACK OF 3D MICE

It's difficult to precisely quantify the impacts of higher product quality, fewer defects, and faster time to market. But with the research results presented here, the economic return from a design engineer's productivity gains can be calculated.

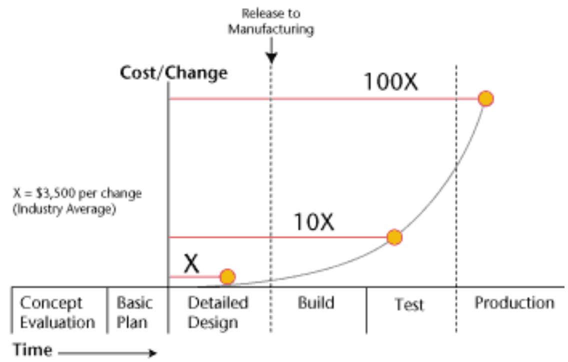
It's paramount, however, to recognize that product quality, fewer defects, and faster time to market represent a much larger financial impact than simply the cost savings from having a more productive CAD design engineer.

As Gavin Finn writes in *Quality Digest*:

> Very real costs are associated with inattention to design quality. If errors or omissions in the design data are not addressed early, more costly changes are required later in the product development process.

This is depicted in Finn's "early detection" diagram, below.

Figure 1: Cost of Changes



Thus, if an economic return can be demonstrated on the design engineers' productivity gains alone, it's reasonable to assume a much higher payback overall.

Three principal factors will drive the ROI of investing in 3D mice for CAD design engineers:

- Cost of the 3D mouse
- Loaded salary of the CAD design engineer
- Productivity gains as a result of 3D mouse use

Companies use two common metrics to evaluate such investments: payback period and annual ROI. Further metrics (NPV, IRR, and so on) will not be discussed in this report but could be easily derived from this data.

4.1 Payback Period and ROI

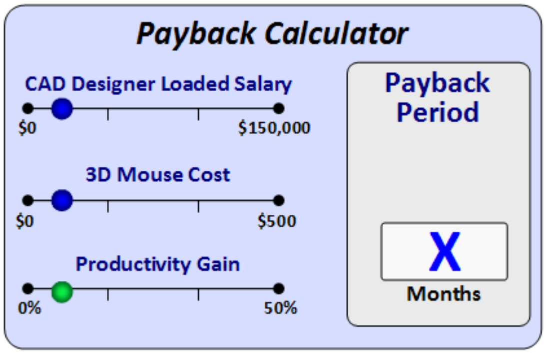
The payback period determines how quickly the investment cost will be fully recovered. The calculation is as follows:

Payback Period in Years =
3D Mouse Cost / (Annual CAD Design Engineer Loaded Salary * Productivity Gain)

As shown in the following illustration, this calculation can be depicted visually in a "payback calculator," in which the user can adjust the three sliders:

- CAD Design Engineer Loaded Salary
- 3D Mouse Cost
- Productivity Gain

The payback calculator would then compute and display the resulting payback period in months.



The ROI calculation measures the ongoing return on an investment—typically on an annualized basis, which gives a more comprehensive financial evaluation. This calculation is:

Annual ROI =
(Annual CAD Design Engineer Loaded-Salary *Productivity Gain) – 3D Mouse Cost) /
3D Mouse Cost

Two of these variables are reasonably straight-forward: the 3D mouse cost and the CAD design engineer's loaded salary. The critical variable—productivity gain—is derived from the survey of 3D mouse users.

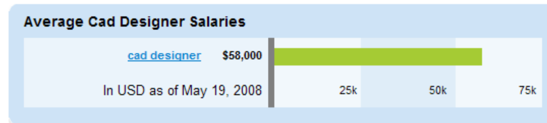
These constitute the inputs into determining expected economic returns on investment in 3D mice for CAD design engineers.

4.2 3D Mice Costs

3Dconnexion's professional 3D mice range from $99 to $399 in price. Many companies select the higher-end professional devices, SpaceExplorer ($299) or SpacePilot ($399), due to their richer feature set. For the purpose of this analysis, we'll use the $399 cost of the SpacePilot.

4.3 CAD Design Engineer Salaries and Costs

Several websites summarize salaries for various job titles. Simply Hired reports the average salary for a CAD design engineer in 2008 as $58,000.



This will of course vary by all the usual factors, including years of experience, location, and industry. In general, 3D CAD design engineers will make more than 2D CAD design engineers.

Employee benefits (vacation, health insurance, and so on) are estimated conservatively at 25% of base salary, resulting in an average benefit-loaded cost of $72,500 per CAD design engineer.

Fully loaded costs (space, equipment, and so on) add another substantial cost multiple. In the absence of solid data, this factor will be ignored in the analysis.

4.4 3D Mice Productivity Gains

The productivity gains from using 3D mice are calculated by taking the average productivity gain reported in the survey and multiplying it by the average percentage of the day that design engineers spend using their 3D CAD applications.

The average productivity gain reported by the 190 3D mouse users was 21%. The average time per day users reported that they used their CAD applications was five hours; a conservative estimate of 50% of their day will be used.

Multiplying these two figures together, we get an average productivity gain of 10.5%.

Now, using the earlier payback period formula of

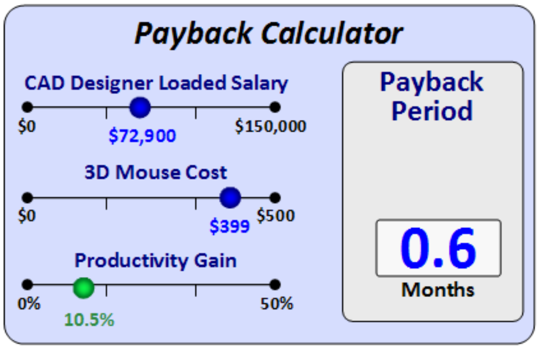
Payback Period in Years =
3D Mouse Cost / (Annual CAD Design Engineer Loaded Salary * Productivity Gain)

we get the following calculation:

$399 / ($72,500 * 10.5%) = .052 years (19 days)

This means that an investment in a 3D mouse will, on average, pay for itself in less than one month.

By adjusting the three payback calculator sliders to these figures, we see the resulting 19-day (= 0.6 month) calculation.



5. CONCLUSIONS

This report purported to evaluate the anecdotal claims that 3D mice can significantly improve CAD design engineer productivity. It further sought to evaluate the user interface research that also suggested impressive productivity gains.

Based on a survey of 190 3D mice users, it appears that in fact substantial gains of more than 20% are being experienced by CAD design engineers while using 3D mice with their CAD applications.

These users further corroborated the underlying user interface research observations that 6DoF navigation and simultaneous two-handedness were the key factors leading to their improvements.

Finally, it was shown that an investment in 3D mice can have an unusually fast payback—less than a month—leading to the conclusion that companies would be well advised to proactively consider adopting 3D mice for their CAD design engineers.

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