



# Effects of Wireless Mobile Technology on Employee Productivity

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Wireless mobility changes the way  
employees work

IT@Intel

Intel IT studied the work habits and productivity of more than 100 Intel employees who were upgraded to wireless notebook computers using Intel® Centrino™ mobile technology. Employees realized a productivity gain of more than two hours per week, more than paying for the cost of the upgrades in the first year. But researchers discovered an even more profound benefit: Wireless mobility rapidly changes the way employees work and gives them more control over their work.

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## Executive Summary

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Give the average Intel employee a wireless notebook computer and he'll get a week's worth of work done in two hours and eight minutes less, a savings of 5 percent of his average work week. That's nearly 100 hours of additional productivity per employee per year, and more than enough to pay for the cost of deploying the new system.

For 25,000 knowledge worker employees, that level of productivity gain is equivalent to adding 1,250 experienced employees to the payroll. However, when we studied the impacts of this migration, we discovered much more than simple added productivity: Continuously connected wireless mobile systems actually changed the way our employees work.

In 2003, Intel began migrating users from Pentium® II processor-based notebook bundles including Microsoft Windows\* 2000 and Microsoft Office\* 2000, to Intel® Centrino™ mobile technology-based notebook bundles with Microsoft Windows XP and Microsoft Office XP. We embarked on a two-phase study to understand the impacts of this wireless mobile migration. We selected more than 100 Intel employees in different offices around the United States and provided them with the same Intel Centrino mobile technology notebook bundles used in our migration. We then studied how this upgrade affected their work habits and productivity.

The first phase of the study, completed in the spring of 2003, *qualitatively* examined road warriors' perceptions of their experience with new notebooks based on Intel Centrino mobile technology. In that study, "The Workplace Hits the Road: Intel IT Assesses Wireless Productivity,"<sup>1</sup> users reported:

- A perceived timesavings of approximately 2.5 hours of work each week.
- Changed work behaviors and locations.
- Choice of work location increasingly based on the availability of wireless hotspot access points.

This paper documents the second phase of the study, which was designed to *quantitatively* understand the impact to productivity and to develop a deeper understanding of the qualitative findings, with knowledge workers in and out of the office. We tested participants in Intel's Human Factors Engineering Usability labs, gathered data from weekly activity logs kept by study participants, evaluated responses to pre- and post-surveys, evaluated actual usage patterns from the records of wireless hotspot access service providers and conducted one-on-one interviews with study participants.

The productivity gains confirmed our business decision to migrate to wireless technology. What surprised us, though, was the pace at which our participants' work behaviors changed during the study:

- Participants reported that small, previously unusable slices of time now became productive, since they needed less time to access e-mail and network files.
- They've begun basing decisions to patronize non-office meeting areas, such as a coffee house, on the availability of a wireless hotspot.
- In many cases, these changes started to occur within days of receiving the system upgrade.

Participants have developed a growing affinity for their notebooks. At the study's end, they asked for more ubiquitous and seamless wireless hotspot access points, so they could connect without thinking about it. And despite the fact that the upgrade more than doubled previous notebook battery life, they wanted even more. In 2004, we will continue to follow this migration as we upgrade our notebooks to run Microsoft Office 2003.

<sup>1</sup> See study at: [http://www.intel.com/ebusiness/it/strategy/wp033101\\_sum.htm](http://www.intel.com/ebusiness/it/strategy/wp033101_sum.htm)

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## Background

Intel set out to mobilize its workforce several years ago, reversing the usual 80:20 desktop-to-mobile ratio for our knowledge workers. The strategy has resulted in increased employee productivity throughout the organization.

Intel IT wanted to understand the business value of such strategies to our company. Traditional measures such as system uptime and network load are important indicators for managing the IT business, but they don't reflect the business value that the solutions deliver.

Since 2001, we've been developing methods to measure the impacts that our IT organization makes on Intel's ability to deliver better products, faster, and at lower cost. By understanding this business value, Intel IT is evolving from a service/infrastructure provider to a true business partner.

Our IT Business Value program defines the methodology for these measurements and actively tracks the business

value of the solutions IT delivers. We're working with industry and academic groups grappling with the same business value challenges, helping to define standard definitions and methodologies to help IT shops value and communicate their contributions.

To learn about other business value studies we've completed, visit [www.intel.com/IT](http://www.intel.com/IT).

## Study Methodology

To understand and explore the impact of wireless mobility on user behavior during the two-month evaluation period, our team employed five data-collection techniques:

- Surveys before and after participants received their new notebooks
- Participant interviews
- Self-report activity logs
- System-generated logs
- Lab-based user performance tests

We used surveys to collect satisfaction data. Surveys are easy to administer and can be collected efficiently from a large number of participants. But since surveys can be impacted by a participant's willingness to respond and other user reporting biases, we also collected other information.

We interviewed participants to gather open-ended responses, to allow for follow-up questions, and to uncover unanticipated information. We also asked participants to keep activity logs capturing how often and for how long activities were performed, defining a core set of activities with clear start and stop points.

Then we reviewed system-generated log files to understand when our participants were performing certain activities. We provided participants with accounts from a wireless hotspot provider, and were able to review the provider's log files. While the log review helped us to determine when an activity occurred, it didn't provide information on what the participant did.

Finally, we asked participants to perform a core set of tasks in a lab setting, allowing us greater control in establishing user performance metrics. Representative participants executed predefined tasks in a controlled setting; we collected completion times, completion rates, and frequency estimates.

Our participants received only standard support for their new notebook bundles, and went through the same notebook computer deployment process and training as our general population.

## Participant recruiting

We recruited 106 participants for the evaluation. We started with the pool of employees slated to be upgraded from their Pentium II processor notebook bundles to the Intel Centrino mobile technology notebook bundles, and randomly selected 1,800. We sent a web-based screener survey to this group and 652 employees responded.

We selected 75 from those 652, basing our selection on criteria including job function, locations consistent with study requirements, mobility/portability needs, hours of work at different locations, and prior experience with wireless systems, to match what we knew about the mobile Intel business notebook user. To ensure appropriate job functions, we chose a proportional cross-section of employees using data from Intel's Human Resources division. Participants represented four major segments:

- Project/program and people management
- Technical support
- Design engineering and programming
- General office and business support (that is, human resources, business analysts, finance)

We further restricted selection to locations that best fulfilled these criteria:

- Fully-deployed wireless infrastructure
- Existing wireless hotspots from our chosen service provider
- As many wireless hotspots in areas around the participant's primary work location as possible

Roughly half of the participants were located at sites with a usability lab, to ensure that we would have sufficient participants for the lab phase of the study (see Appendix A for participant details).

To our 75, we added 31 randomly selected employees from Intel's Sales and Marketing Group (SMG). These employees were using a variety of notebooks (based on either a Pentium II processor, Mobile Intel® Pentium® III Processor – M, or Mobile Intel® Pentium® 4 Processor – M), and had been scheduled for a similar upgrade program.

These selections were based on business unit eligibility to upgrade and the evaluation requirements outlined above.

We excluded two of the 106 users, leaving 104, and planned for a 10 percent attrition rate during the evaluation. Participation in each segment of the study broke down in this manner:

- 39 participants completed the lab study
- 94 filled out both baseline and post surveys
- 35 participated in the initial interview
- 15 of the 35 participated in the final interview
- Nearly everyone from the pool completed the activity logs

## Data presented in this report

We analyzed the data collected in the lab study and survey using statistical tests consistent with the design of the study. But to reduce the complexity of reporting statistical findings in this paper, we don't report specific t-test values.

Statistical analysis typically considers two thresholds to determine if a pattern of results is due to chance: probability of chance is less-than-or-equal-to 5 percent (results are significant), and probability of chance is less-than-or-equal-to 1 percent (results are very significant).

Throughout this report, we consider differences with a probability of chance less-than-or-equal-to 5 percent to be statistically significant and refer to them as "significant."

## Study Details

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### 1. Participant surveys

#### Methodology

We gave participants two web-based surveys, one at the start of the evaluation (baseline) prior to participants receiving their new notebook and one at the end of the evaluation (post). 94 participants completed the baseline and post surveys; all information in this section comes from those results.

We used the same questions in both surveys, adding new questions to the post survey to understand behaviors that emerged during our evaluation. Our questions focused on the time participants spent in different locations, time spent connected (wired or wireless), time spent offline, satisfaction with old and new notebooks, use of accessories, and general comments.

## Study Findings

### Upgrading to wireless mobility improves employee productivity:

- **37.3 percent faster task completion.** Lab study participants completed seven commonly performed office tasks an average 37.3 percent faster using the Intel Centrino mobile technology notebook bundles than with the older Pentium II processor notebook bundles.
- **Improved perceptions of productivity.** In surveys, employees reported a positive impact on their productivity.
- **5 percent weekly timesavings.** Migrating to the Intel Centrino mobile technology notebook bundle would save employees approximately five percent of a typical 40-hour workweek, or about 100 hours per employee per year.
- **Actual gains may be greater.** Employees perform many more than seven work tasks on their computer; non-tested tasks may have similar benefits.

### Wireless mobility changes user behavior:

- **Work locations became more flexible.** Study participants felt they had a greater sense of freedom and more control over where they worked.
- **Employees began “slicing” time.** Wireless mobile computing allowed these employees to make productive use of formerly wasted slices of time between larger tasks.
- **“Time shifting” became commonplace.** Wireless mobility allowed workers to redistribute their working time around professional and personal obligations.
- **Wireless use steadily increased.** As the study progressed, participants increased their use of wireless connections, especially on the Intel campus and at home, sometimes even when a wired connection was available.
- **Notebooks became constant companions.** Wireless connections, longer battery life, and a thinner, lighter form factor led participants to carry—and rely on—their notebooks much more often.

## Survey results

**Higher satisfaction.** Once they’d migrated to the new Intel Centrino mobile technology notebook bundles (post surveys), participants reported much higher user satisfaction and System Usability Scale (SUS)<sup>1</sup> ratings. We modified SUS wording for notebook bundles. SUS scores range from 0 to 100, with a score of 100 indicating a highly usable system.

In Figure 1, on the next page, we show how employees rated their perceptions of both notebook bundles, using the seven-point Likert scale (1=unsatisfied...7=satisfied). Their average satisfaction with the Intel Centrino mobile technology notebook bundle across all vectors was 5.8; while their previous laptops scored significantly lower, with an average of 3.0. The modified SUS yielded an average score of 77.8 for the Intel Centrino mobile technology

notebook bundle, compared with an average of 61 for the older bundle, which is significantly lower.

Participants had been using a variety of pre-upgrade notebooks, including notebooks with a Pentium II processor, Mobile Intel Pentium III Processor – M, or Mobile Intel Pentium 4 Processor – M. Participants who had used notebooks with a Pentium II processor had lower satisfaction ratings and notebook-modified SUS scores than did participants with other platforms; both differences are significant. After the update to the new notebooks, the participants were equally satisfied (see Table 1, on page 7).

**Work locations and connections.** Survey data suggests that participants most rapidly adopted wireless connections within the worksite but outside their immediate workspaces—for example, in conference rooms and public spaces—and many quickly installed

<sup>1</sup> System Usability Scale is a registered trademark of Digital Equipment Corporation, 1986

or began using wireless connections at home. Once wirelessly connected, their use of offline (unconnected) mode dropped to about once per month.

78 percent said they use wireless connections outside their cubicle several times a week or every day. 60 percent use wireless connections at home. Within their cubicle, however, most participants continued to rely on wired connections.

32 percent of those tested told us they were already using wireless either at home or work. These users significantly increased their use of wireless at locations outside their cubicle within the primary site and at coffee shops or restaurants. Participants who did not use wireless before the upgrade tended to adopt it at a slower rate than those already using wireless. However, no significant difference was found.

**Fewer laptop accessories.** Users tended to carry fewer accessories with Intel Centrino mobile technology bundles, effectively making them more mobile. We asked participants to provide information on which notebook accessories they carried onsite at work, going home, and while traveling.

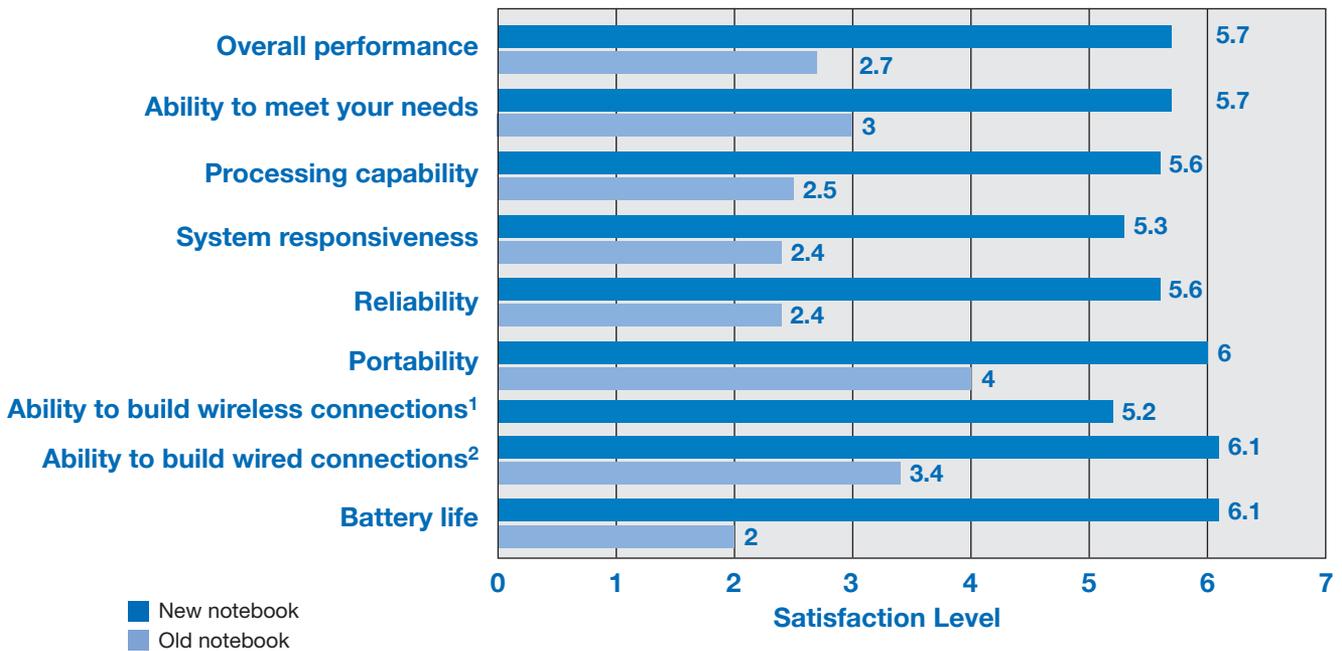
They reported a significant decrease in accessory use at their primary worksite (see Figure 2, on the next page), and also carried significantly fewer accessories when going home (except for PDAs and headphones).

They continued to carry power cords, network cables, and phone cords when traveling. But when making trips, they told us they were more likely to leave external drives, extra batteries, and hardcopy documents at home; this decrease is significant.

**Improved wired and wireless connections.** The new notebooks significantly enhanced making wired connections at other spaces at the primary site, other Intel sites, home, hotels, and public spaces such as convention centers and book stores.

Participants felt that making wireless connection was easy or very easy at Intel facilities, home, and coffee shops or restaurants, while it was still seen as difficult while traveling, or at airports, hotels, customer sites, or public spaces. The participants using wireless before the upgrade found making wireless connections significantly easier at Intel facilities, hotels, airports, coffee shops, restaurants, and public spaces such as book stores and convention centers.

### User Satisfaction Ratings



All measures represent a statistically significant difference between baseline and post surveys.

<sup>1</sup> This rating taken in post survey only.

<sup>2</sup> We asked participants to rate “Ability to connect to networks (Internet or intranet) from any location” in the baseline survey, but “Ability to connect to networks from any location using wired connectivity” in the post survey.

Figure 1. User satisfaction with old and new notebooks (on a seven-point Likert scale)

**Wired importance decreases.** We asked these employees to rate the importance of making wired connections at various locations; in our baseline survey they felt that wired connections were important at Intel facilities, at home, and in hotels. In the post survey, however, wired connections at these locations became significantly less important.

Participants' expectations of wireless connections shifted once they were actually able to make those connections. After migrating to the new notebook bundles, participants

gave increased importance to having wireless connections within Intel facilities.

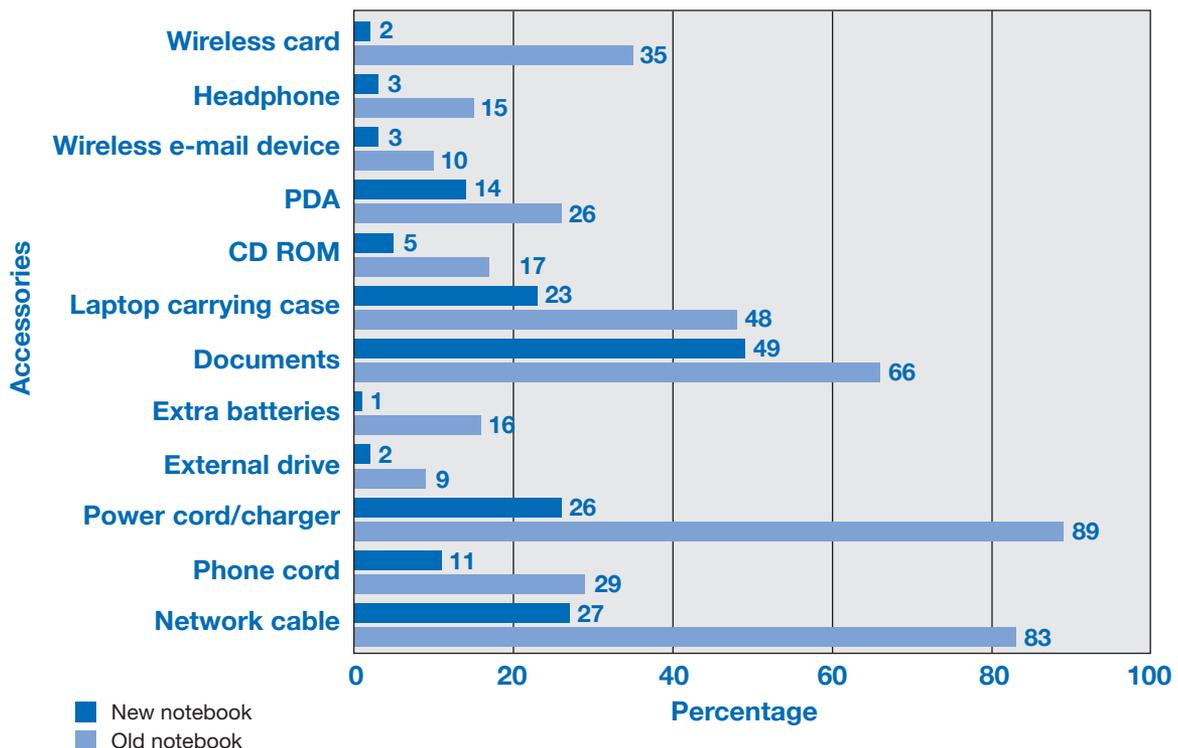
Participants also significantly decreased the importance they gave to having a wireless connection outside office facilities, such as outdoors, in hotels, resorts, and while traveling. That decrease may be due to pre-upgrade expectations meeting up with real-world experience. We'll be performing additional studies to see if external wireless reliance increases as participants grow more comfortable with changing work styles.

**Table 1. Satisfaction and system usability ratings, old versus new notebook bundles**

Original Notebook	Satisfaction with Notebook		System Usability Scale	
	Baseline	Post	Baseline	Post
Pentium® II processor (n=71)	2.8	5.8	59.1	76.7
Mobile Intel® Pentium® III Processor – M and Mobile Intel® Pentium® 4 Processor – M (n=23)	3.5	5.5	67.2	78.2

Note: There was no statistical difference between users who started with different processor-based notebooks.

### Accessories Carried on Site



All measures represent a statistically significant difference between the baseline and post surveys.

**Figure 2. Percentages of users who carried accessories when working on site**

**Positive impacts on productivity.** We asked open-ended questions about what frustrated participants, and what they enjoyed about their current notebooks and the new systems they were given. Content analysis revealed more frustration than enjoyment for the previous notebooks. 61 percent reported that their previous notebooks had negatively impacted their productivity. They primarily enjoyed the fact that their previous notebooks were more mobile than desktops.

Once migrated to the new Intel Centrino mobile technology notebook bundles, however, users expressed more enjoyment than frustration with the bundle. 90 percent reported that the new notebook positively impacted their productivity. They primarily credited three factors:

- Increased mobility supported by longer battery life
- Wireless connections
- Better form factor

**Increased reliance.** Participants frequently mentioned that they often brought their notebook with them to work at different locations, such as conference rooms and public spaces at Intel, and outside coffee shops or cafes, in part because they didn't need to carry so many accessories. Having a wirelessly connected notebook computer allowed them to work more productively at meetings, and utilize previously unusable time.

**Satisfaction with wireless.** 71 percent reported enjoying the wireless capability. But the enjoyment seemed to also raise the bar on participants' expectations of wireless coverage and reliability. 45 percent also noted the wireless connection as a source of frustration. 24 percent expressed a desire for ubiquitous wireless connectivity, including seamless transitions when moving from wired to wireless connections.

**Battery life.** On average, participants estimated battery life of the new notebook to be 3.8 hours and 1.4 hours on the old notebook. It took 3.5 hours to recharge the old notebook after its battery was completely drained, and 1.9 hours to recharge the new one. But increased reliance on the notebook due to longer battery life also brought increased impatience when it wasn't available. More than doubling reported battery life wasn't enough for some users in the study. 19 percent told us they wanted still longer battery life.

## 2. Participant interviews

### Methodology

During the interview phase, we gathered qualitative data to further understand information gathered in the surveys, lab tests, and activity logs. We followed accepted interview practices, using trained interviewers and a script.

We designed the first rounds of interviews to help us understand participants' initial reactions. The final interview explored themes that emerged during the evaluation.

We interviewed 35 participants within an average of nine days after system delivery. Then we performed another set of interviews with 15 of the original 35 at the end of the evaluation, roughly 8 weeks after delivery. Our initial interviews lasted approximately 30 minutes; the final interviews took about 20 minutes.

### Results

**Marked changes in user behavior.** We found that, over the course of the study, participants' behavior and attitudes toward notebook computing had changed dramatically, mostly as a result of the additional mobility brought by reliable, extended battery life and wireless connectivity. After using the new systems for about eight weeks, most interviewees told us they had changed the way they managed their work.

Consistent with other parts of the study, participants told us they felt better able to meet work obligations, and that they had more control over the balance of work and personal obligations. The marked improvement in productivity led to an improved attitude of empowerment.

Initial interviews indicated that many participants anticipated or were already using wireless mobility to productively manage work in meetings, in conference rooms, cafes, client sites, and at home.

In the first week of ownership a majority of those interviewed (71 percent) were already using their systems to quickly and reliably undock the notebook at their desks and carry it, without cables, to conference rooms and public spaces. They told us that several factors contributed to this behavioral change:

- Longer, reliable battery life reduced the need to carry power cables.

“Anyone with wireless capability can use the wireless access at Intel. It’s just that those with Intel Centrino [mobile technology systems have] batteries [that] can last through any meeting.”

- Campus-wide wireless connectivity reduced the need to carry LAN cables.
- Reliable “sleep mode” and docking/undocking resulted in increased confidence in just “shutting the lid” and going.

83 percent of study participants revealed very positive attitudes about their new notebooks in baseline interviews. They said that improvements in performance, battery life, wireless capabilities, and mobility contributed to that perception.

**Older systems constrained users.** A majority (74 percent) of participants interviewed disliked their previous notebooks, describing a lack of confidence in their systems due to poor performance, slow power-up/power-down time, and inadequate battery life. They told us they employed a variety of workaround strategies to accommodate notebook limitations, such as waking up early to start up the system in advance of an early meeting or opening large presentations at client meetings before the meeting starts, to overcome the inconveniences of the older machines.

“As the chair of a meeting it was embarrassing to wait for a large presentation file to load. It used to take an enormous amount of time. And I wasn’t always able to get there fifteen minutes early to pre-boot and pre-load it.”

**Increased reliance on notebooks.** After two months, we interviewed 15 of the original 35 participants; 13 of those spoke of a marked increase in reliance on their systems. Longer battery life and consistent access to wireless connectivity were key factors in this reliance—80 percent stated in exit interviews that extended battery life was an essential component of system reliability—but the easy-to-carry form factor and solid system performance also played an important role.

**Increased time-slicing.** Participants told us they were more apt to time-slice, or squeeze work into small chunks of formerly unused time that reduce the impact on personal time while achieving the same business outcome.

Some participants told us they could more effectively manage commute time by using wireless hotspots. The ability to pull out the notebook and check e-mail, or quickly grab a file, was empowering, especially for participants we tested who also had home networks.

Wireless mobility at home gave participants an additional advantage: they could spot-check their e-mail without leaving family or activities.

“I set up a wireless access point at home and I’m no longer trapped in the den. I can sit with family while I’m getting bits of work done.”

**Better work/life balance.** We worried that participants might view the location flexibility they gained as a further encroachment of “business time” into “personal time.” However, they reported that increased mobility allowed them to flexibly and conveniently manage their work obligations and protect personal time more effectively.

“It’s a new flexibility. It gives me the ability to determine where I want to work from. It lets me be more flexible with my schedule of activities. I’m not locked into being in a certain place at a certain time to do certain work.”

The added flexibility and convenience that allows participants to manage work obligations helps them manage their personal time more effectively as well. Additional investigation is warranted, since company culture plays a role in the user’s perceptions. But in this study, the attitudes expressed about balancing work and family obligations in the exit interviews were uniformly positive.

“Now I have freedom to do what I have to do at all hours. If I have a kid’s soccer game or a dinner party with friends, I know I can do them, and then finish my work later on in the evening.”

**Potential tech support issues.** Two interviewees reported trying unsuccessfully to get their notebooks to work with existing home networks. Also, at least one user spoke of a bad experience with a slow wireless connection during a presentation. We also heard dissatisfaction with the connect times to some software applications.

But these complaints, or reactions to drawbacks of wireless technology, indicate a shift in expectations. Even though most of the participants have had access to wireless computing for less than two months, they have already come to rely on it. They expect total reliability and superior performance; without exception.

“It’s beginning to feel like carrying a cell phone—you don’t think much about it—like carrying a wallet.”

### 3. Self-report activity logs

#### Methodology

We used two types of logs to track participant activity during the course of the evaluation: a self-report log that participants completed each week, and the log generated by the wireless hotspot service provider.

Participants filled out a web-based activity log each week, starting with the week they received their new

notebook computer. These logs captured how long and how often activities were performed. We sent them e-mail reminders each Friday, and another reminder on Monday to those who had not responded. We asked them to report on:

- Number of times and total amount of time spent using wireless connectivity from: home, cubicle, primary Intel site, client sites, airports, cafes, and other locations
- Frequency of use of notebook computer accessories
- Problems with access to wireless hotspots
- A weekly “success story” or an effective, interesting, or novel use of their system
- Difficulties encountered
- General comments

#### Results

Participants didn’t always provide information for every item in the activity log; in these cases, we calculated averages using only data for entries that had been submitted in the log.

**Shift in work locations.** Participants reported shifting wireless use from the cubicle to other areas. In Figure 3, we show the relative distribution of average time participants worked wirelessly at different locations during the first and last two weeks of the study. On average, they reported spending less time working at their cubicle and on campus,

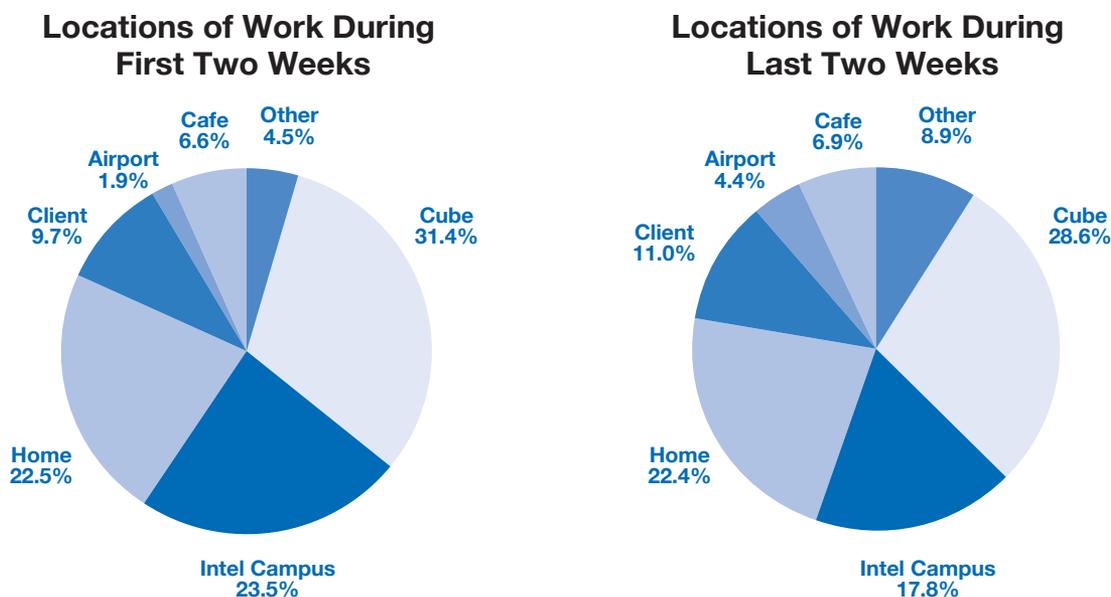


Figure 3. Proportion of time spent using wireless at different locations for first two and last two weeks of the eight-week trial period

and more time working from outside locations such as client locations, airports, and cafes. This data is consistent with what we saw in the survey and interview segments of the study.

“I was attending my son’s soccer tournament on Saturday, and work came up that needed to be finished. Luckily, I had my notebook in the trunk and was able to find a hotspot 5 minutes away. I connected and finished the work. Before I would have been forced to drive home (more than an hour each way), and would have missed most of the tournament.”

Users started carrying their notebooks to meetings and Intel public spaces without accessories, reported that they were more likely to carry their computer with them to meetings, and began relying on battery power for three to four hours at a stretch.

Hotspots provided additional work locations. Access to external hotspots in different locations has led to a number of shifts in work behavior. Users have found several ways to take advantage of outlets as a work resource:

- They work from hotspots when other appointments take them away from the Intel campus.
- They use hotspots in parking lots, hotels, and so on.
- They more readily move to locations with fewer distractions or more privacy.
- They’re more likely to work outside normal business hours to accommodate colleagues and customers in other time zones, since they can readily find connection locations.
- They’ll choose locations more conducive to doing business with customers, suppliers, and other business associates.
- They’ll move to a new work location simply to provide a change of scenery.
- They feel they can better handle emergencies at work in a timely fashion.

Many comments focused on using wireless connectivity in the first weeks (60 percent), dropping to 10 to 20 percent in subsequent weeks, generally covering more novel uses in later weeks. Problems with making wireless connections on Intel campuses (15 percent of comments) and public

hotspots (8 percent of comments) occurred in the first week; both problems dropped to roughly 5 percent in later weeks. Some participants said they would have preferred receiving more training and support on using wireless.

## 4. System-generated logs

### Methodology

We provided an account for a popular wireless hotspot provider to each participant the week they received the new notebook, so that we could better understand how and where participants would use wireless hotspots. The service provider was part of the wireless verification program for Intel Centrino mobile technology.

Roughly 50 percent of the participants didn’t use the account during the evaluation period. 32 percent of the participants reported using a different paid service and 45 percent reported using a free wireless hotspot at least once during the evaluation; we didn’t have the ability to track these records.

### Results

System logs showed that each week averaged 12.5 unique users, connecting on average 2.2 times for approximately

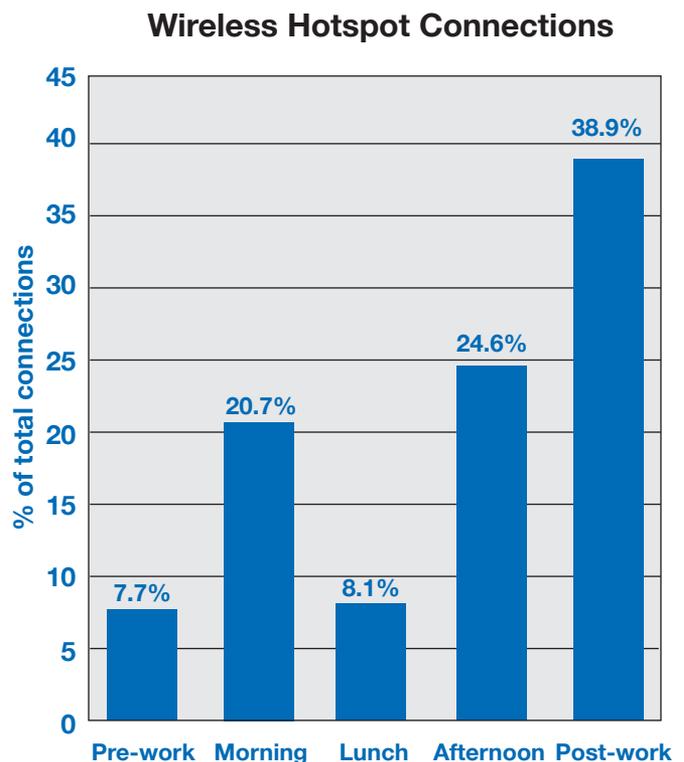


Figure 4. Wireless hotspot connections by time periods

36 minutes per connection, with an average data transfer of 8.56 MB. Participants most frequently connected from coffee shops (79 percent), airports (14 percent) and bookstores (7 percent). Figure 4, on the previous page, shows the breakdown of connections by time of day.

**Perception of wireless hotspots.** While many took advantage of the provided wireless hotspot access, others didn't. We added questions to our final participant survey to better understand the data generated by system logs. For example, we asked them how easy it was to find the service provider's wireless hotspots:

- 45 percent felt it was easy
- 24 percent were neutral
- 31 percent said it was not easy to find these hotspots

We also asked, on the same scale, how important wireless hotspot locations are. For this question 67 percent felt wireless hotspots were important, 17 percent were neutral, and 16 percent didn't find access important. In the end, however, the survey questions created as many questions as they answered.

## 5. Lab-based user performance tests

### Methodology

Our lab study established user performance benchmarks by measuring performance of a defined set of tasks typically performed by the Intel mobile worker. We asked 39 participants, chosen from the overall candidate pool, to perform these tasks on two Intel IT-standard notebook computer configurations (for more on configuration specifications, see Appendix B):

- An **Intel Pentium II processor notebook bundle**, including the Microsoft Windows 2000 operating system and Microsoft Office 2000 software
- An **Intel Centrino mobile technology notebook bundle**, including the Microsoft Windows XP operating system and Microsoft Office XP software

Since we upgrade hardware and software together in a single bundle, we made no attempt to separate the impact of hardware upgrade from the impact of the software upgrade. Instead, we studied the impact of productivity gains produced by the entire notebook bundle.

We selected a sample of typical tasks for mobile workers, and collected performance data and usage frequency

estimates. (For more information on the tasks and the passing criteria, see Appendix C.)

- **Task 1:** Connect to the Intel network from the cubicle. Search for a file, and copy documents from a shared network drive to the local drive for later use when traveling.
- **Task 2:** Work offline while in transit and edit project files while listening to a music CD in the background.
- **Task 3:** Connect to the Intel network using wireless or dial-up connectivity from off-campus location while in transit. Send an e-mail with a document attachment.
- **Task 4:** Perform document edits with the notebook computer connected to the Intel network through wireless or dial-up connectivity from an off-campus location. Send the document through e-mail to team members for review.
- **Task 5:** Move from one location to another due to space conflicts in the Intel office environment. Start the system, begin work, put the system into standby state, carry it to the next location, and return it to the previous working state.
- **Task 6:** Create a PowerPoint\* slide with project-specific data and apply a design template when working online from the cubicle.
- **Task 7:** Propose a new time to the sender of a Microsoft Outlook\* meeting request that does not conflict with any existing appointments.

Test sessions followed standard experimental protocols. To control "learning effects," we randomly assigned the order of test bundles, so that just as many participants started with the Intel Centrino mobile technology system (presented to participants as "Bundle A" to avoid bias) as with the Pentium II processor system ("Bundle B").

At the start of the session, the 39 participants assessed their computer skills:

- 67 percent rated themselves as experienced
- 20 percent saw themselves as self-sufficient
- 13 percent saw themselves as novice computer users

Participants performed the tasks on each notebook bundle, completing survey questions describing their perception of the frequency of the task in their regular work, the bundle's ease of use, and its responsiveness for

that task. We used a seven-point Likert scale to gauge ease of use and responsiveness.

At the end of each notebook bundle test, participants also rated the bundle’s overall effectiveness, efficiency, and their satisfaction with the system, using the System Usability Scale (SUS) survey.

Each session lasted approximately 2.5 hours. Test sessions followed standard experimental protocols. Prior to the next test session, the laptop was reset to the initial state using a standard disk imaging application.

When analyzing data, we omitted data for tasks on *both* systems, if the participant did not successfully complete that task on *each* system. Three pairs of scores were removed.

## Results

Participants’ successful task-completion time was significantly faster, on average 37.3 percent faster on the Intel Centrino mobile technology-based notebook bundle (average time-to-completion: 27 minutes 53 seconds) when compared to the Pentium II processor-based notebook bundle (average time-to-completion: 44 minutes 29 seconds). See Table 2 for a summary of the data.

Participants felt that the Intel Centrino mobile technology notebook bundle was significantly easier to use: the Pentium II processor notebook bundle’s average ease-of-use score was 4.5, while the Intel Centrino mobile technology notebook bundle’s average score was 6.1. Similarly, test participants significantly preferred the responsiveness of the Intel

**Table 2.** Task completion time for matched pairs of passed tasks

Tasks	Pentium® II Processor Notebook Bundle	Intel® Centrino™ Mobile Technology Notebook Bundle
	Average completion times (min:sec)	Average completion times (min:sec)
Task 1 (n=38)	4:29	3:51
Task 2 (n=39)	5:51	3:06
Task 3 (n=38)	13:22	7:09
Task 4 (n=39)	9:21	4:55
Task 5 (n=39)	3:59	4:17
Task 6 (n=39)	5:18	4:02
Task 7 (n=38)	2:09	0:33
Total Time	44:29	27:53

**Table 3.** Average ease of use and system responsiveness ratings, n=39

Tasks	Pentium® II Processor Notebook Bundle Based on a 7-point Likert scale		Intel® Centrino™ Mobile Technology Notebook Bundle Based on a 7-point Likert scale	
	Ease of use	Responsiveness	Ease of use	Responsiveness
Task 1	5.3	4.8	5.9	5.8
Task 2	4.7	4.1	6.1	6.1
Task 3	3.8	2.1	5.8	5.3
Task 4	4.1	2.6	5.9	5.9
Task 5	4.5	3.8	6.2	5.8
Task 6	4.6	4.1	6.1	6.0
Task 7	4.3	3.9	6.7	6.7
Average	4.5	3.6	6.1	5.9

Centrino mobile technology notebook bundle: the Pentium II processor notebook bundle's average responsiveness score was 3.6, versus the Intel Centrino mobile technology notebook bundle's 5.9 score (see Table 3, on the previous page).

SUS data confirmed these findings; participants felt the Intel Centrino mobile technology notebook bundle was superior: the Pentium II processor notebook bundle's average score was 55.7, while the Intel Centrino mobile technology notebook bundle's average score was 82.7. This difference is significant.

We analyzed the successful task completion rates and found that the two bundles didn't differ significantly. The completion rate for the Intel Centrino mobile technology notebook bundle was 272 out of 273; and 271 out of 273 for the Pentium II processor notebook bundle.

## Analysis

### Wireless mobility changes user behavior

Data from all five collection techniques showed a definite shift in participant behavior. While we expected many of the changes we observed, others were unanticipated. These new notebook computers, for example, took on a new importance as a sidekick when employees were away from their desks.

#### Flexible work locations

**Study participants felt they had a greater sense of freedom and more control over their work locations.**

Our evaluation centered on quantifying productivity benefits, but participant employees' perception of having more control over their work/life balance was a nice secondary gain.

Participants told us that moving to Intel Centrino mobile technology made their work more portable and their work time more flexible. They felt that they have a wider range of productive work locations to choose from and don't have to spend so much time traveling to an acceptable work location.

They told us they now select workplaces and times optimized to the task at hand. They can, for example, schedule work outside normal hours to support partners in other parts of the world, choose more appropriate

meeting locations, and multi-task intermittent tasks with non-work activities.

#### Time slicing

**Wireless mobility allowed participants to make productive use of formerly-wasted minutes (slices) of time between tasks.**

Employees participating in the evaluation told us that the wireless notebook bundles allowed them to *time slice*, or convert smaller and smaller slices of time into valuable work time. On their older notebooks, an extra five minutes wouldn't have been enough to allow an employee to plug in, start up the system, connect to a remote network and do useful work.

The new Intel Centrino mobile technology bundles, however, can quickly connect to the network, allowing these participants to check e-mail or perform a fast search on the Web between meetings. The ease of connection, wireless hotspot availability, and performance gains (especially being able to quickly turn systems on and off) let participants become productive in smaller units of time.

Participants reported that they had a more positive sense of "being on top of their work," and were more responsive to team members, clients, and suppliers. This sense was frequently reported in the weekly success stories we had asked them to relay.

"Was able to meet extremely tight planning deadline while on the road for the day meeting with a client. Without Intel Centrino [mobile technology], I would have either missed [the] deadline or would have not taken advantage of the opportunity to meet with the client, which had been in the works for about two months."

Their activity logs showed increasing use of multiple locations over the course of the study, indicating that participants were developing a work style that allowed them to control smaller slices of time.

#### Time shifting

**Wireless mobility allowed workers to distribute working time around work and personal obligations.**

As time slicing became second nature, workers in the study tended to become more adept at *time shifting*, or

arranging their day to optimize effectiveness at work and manage personal obligations. Once wirelessly connected, these employees had an increasing number of places and times to effectively and productively connect to the corporate network.

They could choose to work from new and different locations when those were more convenient than connecting from office or home, and “shifted” their work times as needed to reduce times of low or no productivity. For example, they could more effectively manage commute time by using wireless hotspots.

“The other day I had a dentist appointment, so after I dropped my daughter off at school, instead of making the drive all the way to Intel, and back to the dentist, I stopped at [a] Starbucks [coffee house] and tried out the new [wireless] stuff. Instead of driving back and forth from work, I was able to reply to e-mails while waiting to go to my dentist appointment.”

## Wireless use increases

**As the study progressed, employees increased wireless use, especially on the Intel campus and at home, sometimes even when a wired connection was available.**

Participants told us that the wireless notebook connection, combined with the notebook’s improved battery life and form factor, induced them to increasingly use the notebook away from their desk. Although the wired connection was faster, most viewed the speed and performance of wireless as “good enough” in all but a few situations.

Some participants told us they’d even begun using wireless at their desks, despite the availability of the wired connection. Most regarded wireless connections throughout Intel facilities, and at home, hotels, and airports as highly important.

## Notebooks become constant companions

**Wireless connections, longer battery life, and more portable form factor meant participants started regarding their notebooks as a constant companion.**

Making the notebook easier to carry—and more connected at more destinations—helped these employees carry the notebook computer as easily as they formerly carried paper-filled notebooks.

Participants told us the new notebook bundles were light enough to be easily ported from meeting to meeting. Due to its longer battery life and wireless connection, employees could carry the notebook by itself (without case, power cords, and network cables). They told us it soon became commonplace to rely on the notebook as a constantly available resource.

Participants seemed to adopt the technology at different rates. Many adopted it quickly and took every advantage of the new systems within a few weeks. Others adopted the technology at a slower rate but were taking advantage of the new capabilities by the end of the two-month evaluation.

Roughly 10 percent have been slow to take full advantage of the technology. This may indicate the need for additional training or support for employees less inclined to adopt new technologies.

## Calculating the economic value of productivity

If productivity improvement is directly attributable to a new project, then the value of the productivity is the value of the output of the new project. We evaluated the financial value of increased worker productivity attributable to upgrading to an Intel Centrino mobile technology-based notebook bundle from two perspectives: the cost of each employee’s time, and the benefit to the corporation of its employees’ output.

The first perspective is a straightforward calculation:  
Productivity value = Time saved x Employee cost

Based on the seven tasks we chose to evaluate, migrating to the Intel Centrino mobile technology notebook bundle would save our employees approximately 5 percent of a typical 40-hour work week (see Table 4, on the next page).

Assuming that the benefit of upgrading workers to the faster configuration is then 5 percent of the employee’s total cost, a company with 25,000 employees and a per-employee total cost/burden of \$100,000 would realize approximately \$125 million annual benefit from the upgrade. The annual benefit per employee would be \$5000, or nearly 100 hours.

But for a company to be profitable, their investment in workers must exceed total employee cost. Simply to value employees’ time at their annual burden rate undervalues their true output and the return on the company’s

**Table 4. Average time savings for upgrading to the Intel® Centrino™ mobile technology notebook**

Tasks	Pentium® II Processor Notebook Bundle	Intel® Centrino™ Mobile Technology Notebook Bundle	Difference	Frequency of Use per Week	Total Difference per Week
	Average in seconds	Average in seconds	In seconds		In seconds
Task 1	268.74	230.87	37.87	27.13	1,027.41
Task 2	351.00	185.86	165.14	2.87	473.95
Task 3	802.00	429.18	372.82	3.04	1,133.37
Task 4	560.72	295.38	265.34	2.96	785.40
Task 5	239.33	257.05	-17.72	17.69	-313.46
Task 6	318.44	242.44	76.00	19.78	1,503.28
Task 7	128.53	32.84	95.69	32.3	3,090.79
<b>Total</b>					<b>7,700.74</b>

investment. We feel that identifying the value of gained employee time from productivity increases is probably a better assessment of the true value of an upgrade’s productivity enhancement.

By that measure, upgrading to the faster, more powerful configuration would realize an annual increase of 2.5 million employee work hours. That’s the equivalent of adding 1,250 skilled, experienced employees to the payroll.

## Conclusion

Originally, we intended this evaluation to measure employee productivity gains from upgrading a Pentium II processor-based notebook with Microsoft Windows 2000 and Microsoft Office 2000 to an Intel Centrino mobile technology-based notebook with Microsoft Windows XP and Microsoft Office XP. We knew the processor was faster, the software was upgraded, wireless capabilities were present, battery life was longer, and the notebook weighed less.

The seven common tasks tested in the evaluation showed a weekly timesavings in excess of two hours. The productivity gains from these seven tasks alone will more than pay for the cost to upgrade during the first year of deployment, and there is a strong probability that there will be additional time savings from the other tasks Intel employees perform during the work day.

What we didn’t know was that we were not simply studying an evolutionary upgrade of a mobile platform, we were also uncovering behavioral changes: wireless mobility changes the way people work. We have started using terms such as *time slicing*, *time shifting* and *constant companion* to describe how people are changing their work practices.

“I had to wait during a child’s appointment one evening; I went to a hotspot, pulled down my e-mail and worked on an urgent issue. It was great to have the flexibility to do this so I didn’t have to log on when I got home at 9:30 that evening.”

We expected some changes, of course, but what we didn’t expect was the rapid adoption of the change. Employees in this study changed these work habits in the first weeks of receiving the upgraded systems.

We worried that this change might force further intrusions of work on employees’ personal time; in fact, we were told that just the opposite happens. Employees given the Intel Centrino mobile technology upgrade felt they were more able to manage commitments and their time.

As our roadmap continues to evolve—to faster processors, improved technologies, and a move to new software (including Microsoft Office 2003)—we plan to pursue further investigations to understand these evolving changes in our mobile workforce.

## Appendix A: Participant Segment Details

*Table A1. Job family segment for lab participants*

Number of Participants	Employee Segment
17	Project, People, Program Managers, and Administrative Assistants
1	Technical Support
12	Business/Marketing Planning/Analysts, Financial Analysts, Manufacturing, Supply Chain Management, Quality Assurance, Technical Planning, Human Resources, Sales and Marketing Group
9	Software Engineering, Design Engineering, Hardware Engineering, Product Engineering, CAD Engineering, Systems Engineering, Programming and Web Development
39 <sup>1</sup>	Total participants

<sup>1</sup> A total of 43 participants participated in the lab tests. Four were removed from the analysis due to schedule conflicts that didn't allow completion of all tasks and errors made by test administrators, resulting in incomplete data sets.

*Table A2. Job family segment for survey participants*

Number of Participants	Employee Segment
38	Project, People, Program Managers, and Administrative Assistants
3	Technical Support
35	Business/Marketing Planning/Analysts, Financial Analysts, Manufacturing, Supply Chain Management, Quality Assurance, Technical Planning, Human Resources, Sales and Marketing Group
18	Software Engineering, Design Engineering, Hardware Engineering, Product Engineering, CAD Engineering, Systems Engineering, Programming and Web Development
94 <sup>2</sup>	Total participants

<sup>2</sup> Some participants didn't provide answers to this question, current job description data available online was used.

## Appendix B: Hardware/Software Specifications

### Intel Centrino mobile technology notebook bundle

Notebook with:

- 1.50 GHz Pentium® M processor, in the Intel Centrino mobile technology configuration (in conjunction with the Intel® 855 Chipset family and the Intel® PRO/Wireless 2100 Network Connection)
- 1 MB L2 cache
- 512 MB SDRAM SO DIMMs PC2100 at 266 MHz
- 40 GB 5400 rpm hard disk drive
- 14.1 XGA (1024x768) TFT LCD
- 32 MB ATI Radeon\* 7500
- Microsoft Windows XP Pro 5.1.2600 SP1
- Microsoft Office XP SP2

### Pentium II processor notebook bundle

Notebook with:

- 400 MHz Pentium II processor
- 256 KB on-board cache
- 128 MB SDRAM SO DIMM at 66 MHz
- 10 GB hard disk drive
- 13.3 XGA TFT AGP 64-bit 2.5 MB VRAM
- Microsoft Windows 2000 5.00.2195 SP3
- Microsoft Office 2000 SP3

## Appendix C: Lab Study Tasks and Scenarios

Task	Scenario	Task Description	Passing Criteria
1	It is 3:00 pm in the afternoon and you are back at your cubicle after a 2-hour meeting in a conference room. In a few minutes, you will be leaving to catch the Intel shuttle to attend a face-to-face customer meeting in Seattle and then work from the Intel Dupont site. You want to make changes to the Intel® Centrino™ mobile technology project plan document while traveling and you need to copy some key documents from the project's shared drive and save them in the local folder.	<ol style="list-style-type: none"> <li>1. Connect the notebook to the docking station. Open the notebook cover and come out of standby mode.</li> <li>2. Copy two specified documents from a specified folder and paste them locally in a specified folder.</li> <li>3. Search for the files titled "UsersData" on the local system and save the most recent version of the file "UsersData" in a specified folder.</li> <li>4. Put the notebook back into standby mode.</li> </ol>	Successful copying of the files and putting the notebook in standby mode.
	Familiarization Video <sup>1</sup>		
2	You are in flight and will be working offline editing some project files. You want to add "UsersData Version 2.xls" data to your "Intel Centrino Mobile Technology Study Plan Version 1.doc" document. You are listening to the music from a CD player in the background.	<ol style="list-style-type: none"> <li>1. Copy the data from a specified Microsoft Excel* file.</li> <li>2. Paste the data into page 4 below the text in red in a specified Microsoft Word* document and format it as shown in the sample.</li> <li>3. Save it as a specified file name in a specified folder.</li> <li>4. Prepare and save an e-mail draft for sending this document for review to specified project members.</li> </ol>	Successful creation and saving of the e-mail to be sent.
	Familiarization Video		
3	You just arrived at the San Francisco airport. You want to send the previously created e-mail draft containing "Intel Centrino Mobile Technology Study Plan Version 2.doc" file for review.	<ol style="list-style-type: none"> <li>1. Take the computer out of the carry bag and start the computer.</li> <li>2. Connect to Intel network either wirelessly or by using dial-up access.</li> <li>3. Open the saved e-mail in Microsoft Outlook* with the subject "Please review 'Intel Centrino Mobile Technology Study Plan Version 2'" from a specified folder and send it.</li> <li>4. Close the application and shut down the notebook.</li> <li>5. Put the system back in the bag.</li> </ol>	Successful sending of e-mail with the attachment and shutting down the notebook.
	Familiarization Video		

*continued on next page*

<sup>1</sup> At four points during the lab test session, familiarization tasks ensured that the participant was familiar with the features to be tested in an upcoming task. A video file, created previously for each familiarization task using a standard capture program, was played back to the participant on the system. This ensured a standard presentation of the familiarization information.

Task	Scenario	Task Description	Passing Criteria
4	<p>You checked into a hotel an hour ago in Seattle with wireless or dial-up modem connectivity. You just logged on to the Intel network and observed that the e-mails from two project members, with their revisions, have arrived in the Inbox. You want to accept the changes made by those two reviewers. You also want to send another document on mobile technology to both project members.</p>	<ol style="list-style-type: none"> <li>1. Open the e-mail that you received from project member 1 and open the attachment (the reviewed document).</li> <li>2. Open the e-mail that you received from project member 2 and open the attachment (the reviewed document).</li> <li>3. Accept all changes and merge the changes in the two documents.</li> <li>4. Save the document with the merged changes as "Intel Centrino Mobile Technology Study Plan Version 3.doc" in a specified folder.</li> <li>5. Open the other document that you saved in the specified folder, and send it to both project members as an attachment.</li> </ol>	<p>Successful merging of documents and sending of e-mail.</p>
5	<p>The following day you are having a face-to-face Intel Centrino mobile technology project monthly status update meeting with project members at Intel Dupont. You are sitting in one of the conference rooms and have logged to the network. Just when the meeting is about to start, you are all asked to leave the room as it has been booked by someone else. You carry notebook to the next room. You want to open a presentation that the project member 1 sent you in an e-mail as his pre-work to the meeting.</p>	<ol style="list-style-type: none"> <li>1. Start the notebook from standby mode and then connect to Intel network.</li> <li>2. In Outlook, find an e-mail from project member 1 with a specified subject and open it. Open the attached PowerPoint* file.</li> <li>3. Now, as if interrupted in the conference room, put the machine into the standby mode.</li> <li>4. Stand up briefly for a second and sit back on the seat.</li> <li>5. Bring the machine out of standby mode by opening the lid.</li> <li>6. Open the e-mail and the attached presentation again. As if in a presentation session, move from slide 1 to slide 2 in the document.</li> <li>7. Close PowerPoint and all other applications. Put machine into standby mode.</li> </ol> <p>Note: For Intel Centrino mobile technology systems, the participants did not connect or disconnect the power cable or LAN cable when starting or stopping the system. However, they did turn the radio on and off, and connected and disconnected using a virtual private network (VPN) connection to the Intel network. For Pentium® II processor-based systems, LAN cable and power adapter were connected and disconnected for starting and stopping the system. Both bundles had Outlook set to synchronize upon exiting the application.</p>	<p>Successful moving from point A to point B. Opening the presentation and then closing it. Putting the system in standby mode. Disconnecting and collecting all the cables.</p>
	Familiarization Video		

*continued on next page*

Task	Scenario	Task Description	Passing Criteria
6	You are back in your office in Folsom. During the yesterday's status update meeting in Intel Dupont, some of the project members made suggestions to you to add a single-slide chart and table with the data on weights of notebooks based on three Intel processors. Your colleague, project member 2, sent the data you needed through an e-mail. You want to create a PowerPoint slide showing the weight in pounds for the notebook models based on the three Intel processors.	<ol style="list-style-type: none"> <li>1. Open Outlook. Open the e-mail from project member 2.</li> <li>2. Create a new PowerPoint presentation document for adding a table and a chart in a single slide.</li> <li>3. Create a table with the data in the e-mail. Also, create a bar chart using the same data.</li> <li>4. Name the slide title as "Notebook Weight." Apply the document template called "Intel IT" from the Design Templates.</li> <li>5. Save the file as "Notebook Weight.ppt" in a specified folder.</li> </ol>	Creating a table and chart in one slide and saving the PowerPoint file after applying the design template.
	Familiarization Video <sup>1</sup>		
7	Your administrative assistant, project member 6, sent you a meeting request to prepare an agenda for the next month's Intel Centrino mobile technology project update meeting. The meeting time conflicts with your current schedule. You need to propose a different meeting time to project member 3.	<ol style="list-style-type: none"> <li>1. Open Outlook. Open the meeting request form project member 3.</li> <li>2. Propose a new meeting time that does not conflict with your schedule or project member 6's schedule.</li> </ol>	Declining the meeting and proposing a new time before sending.

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