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— WHEEL ON TRIAL —

$10 Million Industry Research Project Flops

Motorola Ferris Wheel for Exposing Animals Confounds Cell-Phone Cancer Studies

PERFORM A is a washout. The eight-year, $10 million industry research project that was supposed to answer the question, "Does cell-phone radiation cause cancer in animals?" instead promises to sow more confusion and mistrust.

The project consists of six long-term experiments, carried out on mice and rats in four European laboratories. Most everyone connected to **PERFORM A**—from the researchers who did the work to the cell phone industry that sponsored it—says that it sounds an all-clear: Cell phones are cancer-safe.

Details on the 19 Animal Studies on Cell Phone Radiation, 1997–2007, are on pp.14-16

In fact, the studies tell us practically nothing. They are impossible to interpret because of a flaw common to all six experiments. The animals were restrained in a fixed position during the radiation exposures and that restraint had a profound impact. There is now no way to disentangle the effect of the exposure system from that of the radiation.

That an exposure system can confound an experiment is nothing new. What is surprising is that the managers of the PERFORM A project disregarded numerous warning signs. Their own preliminary studies pointed to the fact that animals suffered from restraint stress, as could have been predicted from reading the easily accessible scientific literature. And when confronted with the final results of their six experiments, which showed that something had gone terribly wrong, the project team simply looked the other way.

What follows is a story that illustrates what happens when engineering takes precedence over biology and when inconvenient scientific findings are ignored. But most of all, it shows the perils posed by industry-sponsored research where those in charge are pushing for the desired results.

(continued on p.2)

Comparing Cage Controls and Shams: A Stress Test

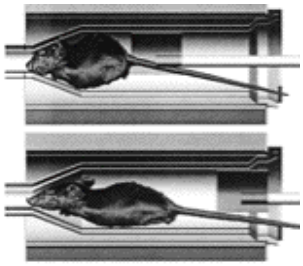
Standard practice in animal experiments dictates that the way you tell whether an agent has an effect is by comparing one group of animals that is given the agent with a second group that is not. The two sets of animals are handled exactly the same way, and both are put in the exposure apparatus. But one group is not actually exposed to the agent —these latter animals are called the "sham controls" or more simply the "shams." A third group of animals is also needed to check whether the apparatus itself and how the animals are handled have an effect. These so-called cage controls are set aside from the others and are allowed to run free for the life of the study; these animals are never subjected to the experimental manipulation associated with the exposure. The cage controls are the comparison group for the shams, much like the shams are the comparison group for the exposed animals. Cage controls are easy to include, though they do add to the overall cost of the experiment.

In the PERFORM A experiments, mice and rats were placed in tight-fitting plastic tubes that were housed in a Ferris wheel-like apparatus with a plunger-like device to stop the animals from backing out (see figures). An antenna at the center of the wheel exposed the animals to cell-phone radiation. In each experiment, there were two sets of wheels, one for the shams and one for the animals who got the radiation. Only these two groups spent any time in the Ferris wheel. The cage controls were kept away.

Ferris wheel for rats

The graph on page 3 illustrates what happened in one of the PERFORM A experiments. It is a slide from a presentation by Robert Hruby of the Austrian Research Center in Seibersdorf (**ARCS**). In this **study**, 500 rats were given a single dose of DMBA, a chemical that is known to cause breast cancer. Three groups of 100 rats each were then exposed to cell-phone (GSM) radiation—each group at a different dose—to determine whether it would increase the number or the size of the chemically induced tumors. Another group of 100 rats, the shams, were placed in the Ferris wheel but got no radiation, and the last 100 rats served as the cage controls. Once a week, the animals were examined by hand to see if they had developed lumps in their chest or abdomen (this is called palpation). The five curves show the percentage of rats with masses that were big enough and distinct enough to be identified by touch.

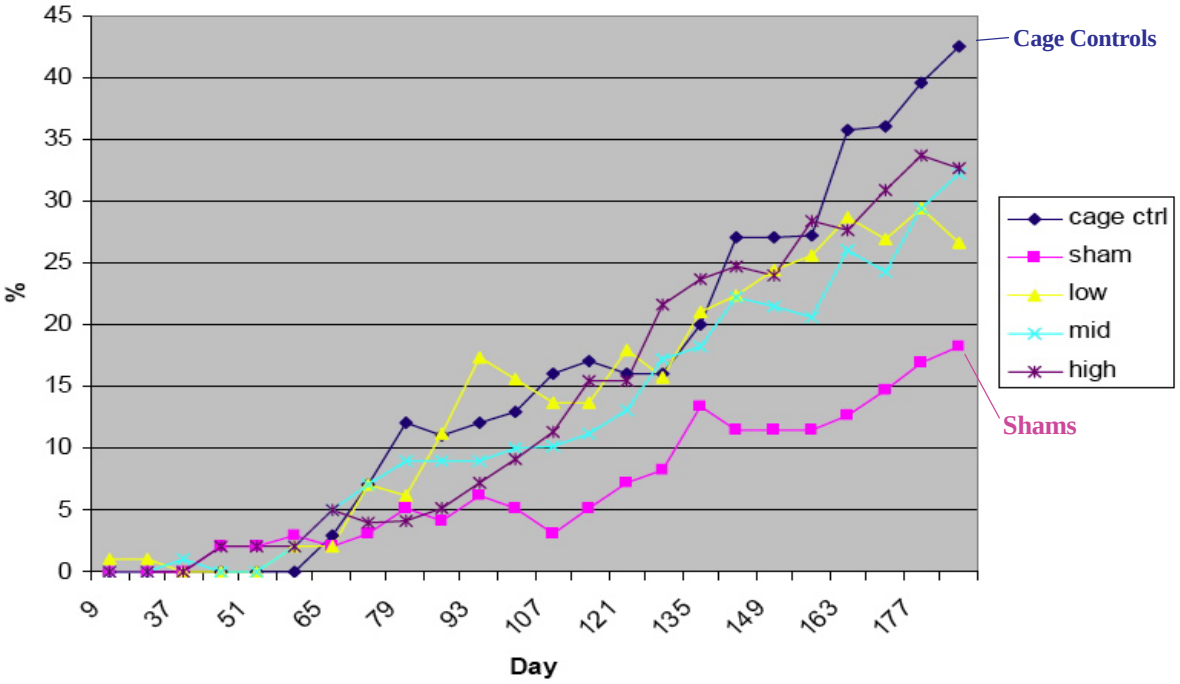
Ignore for the moment the three middle curves, which show how the RF-exposed rats fared. Compare instead the blue curve on top (the cage controls) with the pink curve on the bottom (the shams). More than twice as many cage-control rats (43%) had masses compared with the shams (19%). The Austrians acknowledge that this is a statistically significant difference.


Mice in tubes with stopper

Huai Chiang, at the **Zhejiang School of Medicine** in Hangzhou, China, had already completed exactly the same DMBA-GSM **experiment**.This was a follow-up study to Hruby's, but Chiang finished first. (The China project was a PERFORM add-on, wholly funded by the industry.) She found just about the same large differences as Hruby: 41% of her cage-control rats had palpable masses, compared with only 19% of her shams. The two sets of results are—at least in this respect—consistent. One could say that the Austrians and Chinese had replicated each other's findings, the standard test for the reliability of scientific observations.

Checking for breast tumors in live animals gives a different tumor count than looking for them at autopsy. Palpation misses many tumors because some are too small, some are too soft and some are simply hard to detect by hand. Both Hruby and Chiang examined the dead rats' tissue under a microscope (this is called histopathology) and, as expected, each found many that had been missed by palpation. But, both still saw more tumors among the cage controls compared with the shams. The two experiments did diverge in one important respect: the type of tumor—malignant or benign—that was inhibited among the shams. Chiang found three times as many benign tumors among the cage controls, while Hruby found 50% more malignant tumors in the cage controls (see table on p.14).

Chiang blames the rats' feeding schedule, not restraint stress, for the difference in tumors between her shams and cage controls. The exposed and sham rats were denied food



Cumulative percentage of female rats with palpable mammary gland tissue masses (Hruby et al., presented at the European Bioelectromagnetics Association meeting, Bordeaux, April 2007). Note the difference between the cage controls and the shams.

for up to five hours when they were in the Ferris wheel or on their way to and from their cages. The shams were, on average, 10% lighter than the cage controls and, as Chiang points out, restricting food intake can inhibit breast tumors in both rats and mice. Chiang makes it clear that the Ferris wheel had messed up her experiment and that she would never use it again.

Hruby, on the other hand, found that the weights of the cage control rats and the shams were about the same, and he does not even raise the food issue. He does raise the possibility of restraint stress, but rejects it. The difference in tumor rates is simply a chance outcome, Hruby says, because stress does not reduce the incidence of tumors.

Hruby should have known better. Over 30 years ago, **Benjamin Newberry** showed that restraint stress could protect against tumors. As it turns out, Newberry had done just about the same experiment as Chiang and Hruby—except for the radiation exposures. Newberry had used the same strain of rats, Sprague-Dawley, and had given them the same cancer-causing chemical, DMBA, before restraining them. "Post-induction restraint is sufficient to inhibit the development of palpable tumors in response to DMBA," he concluded in a **paper** published in the September 1978 issue of the *Journal of the National Cancer Institute*.

Stress can promote tumors or protect against them or do nothing," Newberry explained in a recent interview from Kent State University in Ohio, "It all depends on the exact parameters of the experiment." Newberry said that there is a "huge literature" on the effects of stress on tumor development. His paper was consistent with other work published in the 1970s. For instance, a year before his paper came out, two researchers from the Johns Hopkins University School of Public Health **wrote** in *Science* that "environmental stressors not only can depress immune response, but can also enhance it."

In order words, stress can be good or bad for you. This observation —as well as the fact that the Ferris wheel might cause stress in the first place—seems to have gotten lost by the PERFORM A team.

Carousels: What Goes Around Doesn't Come Around

Cell-phone animal studies are neither easy nor cheap. When designing an experiment, you are faced with a number of decisions: Whether to expose the whole animal or primarily its head. Whether to restrain them or let them roam free in their cages. Whether to expose the animals individually or in groups. And of course: What species? Which strain? What dose?

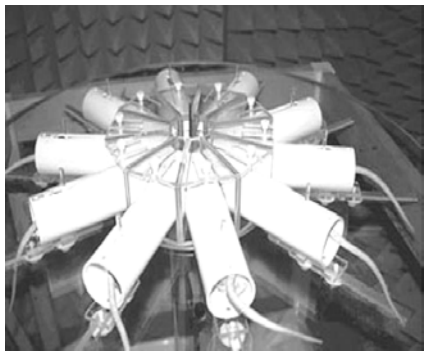
Motorola was the first to grapple with these questions. Most people use their cell phones by holding them just a few millimeters away from their head, so it made sense that Motorola placed a transmitter similarly close to the animals' heads. This turns out to be more difficult than it might at first appear. At that distance, the head is in what is known as the antenna's "near field," where the electric and magnetic components of the radiation can vary considerably from one spot to another. To give the animal a well-defined dose of radiation, the animal's movement has to be restricted. If it wiggles its head, for instance, the amount of energy going into the brain would vary widely. According to one calculation, a movement of just 15 millimeters (a little more than half an inch) would reduce the radiation dose by about 30%. Restraint has its own downside: It can trigger stress.

It's hard to get the dose right without affecting the animal. If the rats or the mice can roam around freely, their radiation exposure is uncertain. On the other hand, if you restrain them to keep them in one position during the exposures, they are more likely to feel stress. It's a type of uncertainty principle: The more you know about the dose, the less you know about the biology.

About 20 years ago, Q. Balzano, at the time Motorola's chief scientist, devised a near-field exposure system consisting of ten cylindrical tubes arranged radially around a central antenna. Each tube could house a rat with its snout some 30 to 40 millimeters away from the antenna (see figure at right). A small plastic plunger was fitted at the rat's rear end to make sure it could not back up. From the very beginning, everyone knew that rats in the carousel might feel stress. In the first detailed description of Balzano's carousel system, **Niels Kuster** and his then-student Michael Burkhardt, at the Swiss Institute of Technology in Zurich, known as **ETH Zurich**, **cautioned** that stress restraint could mask effects of the radiation.

In 1992, Motorola commissioned **Ross Adey** of the VA Hospital in Loma Linda, CA, to run two long-term rat studies using the carousel. A medical doctor by training, Adey had been a senior member of the UCLA's Brain Research Institute before moving to Loma Linda. Adey went forward with the experiments, but he kept wondering whether immobilizing the rats in the carousel tubes for two hours a day could cause enough stress to "markedly alter" the number of tumors they developed.

Adey used cage controls in only one of his two Motorola studies, and as it turned out, he found no big differences in the survival or in the tumor incidence of the cage controls compared with the shams—those that had been in the carousel without radiation exposure. Nor had he seen any signs of stress. After a training period of only one week, the rats would "freely enter the tubes and often slept through the exposures," Adey **reported**.



Balzano's rat carousel

Yet Adey still had some doubts. In November 1995, he had come across an abstract, by Firdaus Dhabhar and Bruce McEwen of Rockefeller University, indicating that rats showed measurable signs of stress after two hours in a glass restraining tube—the same amount of time Adey's rats had spent in the carousel. "They hate it," Dhabhar told ***The New York Times*** at the annual meeting of the Society for Neuroscience. They reported that the tubes do not squeeze or harm the rats in any way, but you can still measure an uptick in their stress hormones. The stress response is a double-edged sword, McEwen told the *Times;* a moderate amount may be beneficial, but too much is clearly bad.

The Rockefeller findings were exactly what Adey was worried about. In a memo distributed to his research group, Adey suggested that they bring up the Dhabhar-McEwen work at a meeting with their Motorola sponsors to be held in Fort Lauderdale, Florida, a couple of months later. Motorola ended up funding some follow-up studies, and these would confirm Adey's suspicions. In April 2001, Adey **reported** that restraining rats—even loosely—in plastic tubes induced a "significant stress response." He closed his paper with a warning:

> Careful monitoring, with comparison to unstressed

cage control animals, and minimization of the immobilization/handling stress required to expose the rats to the RF near field must be essential components of any experiment designed to evaluate potential bioeffects of RF fields.

What Adey called "essential" would soon be deemed unnecessary.

From Carousel to Ferris Wheel: From Near Field to Far Field

Between the times that Adey finished his two animal experiments and their publication in journals, Mike Repacholi caused an international sensation with the results of his own animal study. In April 1997, he published a paper showing that mice chronically exposed to digital cellphone radiation had a higher risk of cancer (see ***MWN*, M/J97**). "The statistical probability that the apparent increase was due to chance was calculated to be less than 1%," Repacholi reported. The study had been carried out at the Royal Adelaide Hospital in Australia, where Repacholi had previously been chief scientist.

Repacholi had a reputation for being industry-friendly. (Today, he is an industry consultant for hire.) Thus, his paper caught people off guard in a Nixon-going-to-China kind of way, and it gained instant credibility. Repacholi had shopped the paper around to many of the world's leading journals, including *The Lancet, Nature* and *Science* before settling for the more specialized *Radiation Research.* It took about two years to get the paper in print, and by then, the spring of 1997, Repacholi had moved to Geneva to run the International **EMF Project** at the World Health Organization. His association with the WHO added even more weight to a possible cell phone–cancer link.

To no one's surprise, the cell phone industry tried to play down the Repacholi study. "These findings cannot be directly related to human health or to the safety of mobile communications," said Mays Swicord, a retired FDA official who had set out on a second career as Motorola's director of biological research. But the industry perspective was not getting much traction and its troubles were not going away. The editorial board at the *Jerusalem Post,* for instance, drew parallels between cell phones and cigarettes, calling the Repacholi study "A Cellular Wake-Up Call" for the industry. "The research certainly demands immediate and serious attention," the editors wrote.

Motorola continued to throw cold water on the Repacholi study. "There is no possibility that mobile phones are involved in a cancer scenario because the power output of phones is just too low," Ken Joyner, Motorola's point man on health for Asia and the Pacific, told the *Australian Financial Review.* Nevertheless, everyone, even those at Motorola, knew that the study had to be repeated. And so it would be. In 1998, the Australian government funded a replication effort at the Institute of Medical and Veterinary Science in Adelaide under the direction of Tim Kuchel and Tammy Utteridge. The head of the institute declared that the new study would provide a "definitive" answer to the question, "Can mobile phone-type radiation cause cancer in animal systems?"

Repacholi had used a completely different exposure system than Adey. Instead of restraining the animals individually in the near field, Repacholi had housed five mice in each cage and allowed them to move freely in the far field. Restraint stress would not come into play with this setup. On the other hand, the dose of radiation the mice received varied widely, depending on their size and position in the cage as well as whether they were huddled together, some shielding the others from the transmitter. The lack of a precise dose was heavily criticized. "We did not have the resources to hold the mice during exposure and irradiate them with a special antenna in the near field," Repacholi told us soon after his paper was published.

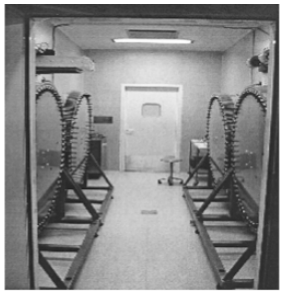
Balzano came up with a new design, the Ferris wheel, which, he promised, could deliver a "precisely quantifiable" dose of microwave radiation with "excellent" uniformity. One key difference from his carousel is that animals in the Ferris wheel are exposed in the far field. The wheel could help determine whether the Repacholi cancer risk could be replicated, but at the cost of abandoning simulating human use of cell phones with near-field exposures.

The Ferris wheel offered some major advantages. The most important was that it was much cheaper than any of the alternatives. The Ferris wheel would allow more animals to be exposed with less equipment and in a smaller lab space than the other available systems. A number of wheels—some for the exposed animals and some for the shams—could easily share the same room. Motorola supplied Kuchel and Utteridge with the Ferris wheel exposure system for the replication effort at a cost of between half a million and a million dollars.

If animals in the carousel tubes were under stress, how would they react when the tubes were placed in the Ferris

wheel? The mice would be even further removed from their normal environment. Would this cause more stress? There is no record that this was ever considered. As one observer told us, "No one considered that possibility."

The Kuchel-Utteridge paper appeared in 2002 and quickly became as controversial as Repacholi's. The replication had failed: The Australians reported that the radiation did not increase the cancer rate. But what should have been a triumph for the cell-phone industry was overshadowed by the widespread view that the Australians had botched the job.* Both Balzano and Repacholi, among others, were harshly critical. "The paper is chock-full of contradictions," Balzano told *Microwave News* after reading their paper in *Radiation Research*. Repacholi was equally dismissive: "I'll wait for the second replication," he told us, referring to the PERFORM A study that was under way in Torino, Italy.



Many wheels in one room

Despite Motorola's best efforts, the amount of radiation given to the mice in the Ferris wheel was still hard to pin down. When the mice were young, for instance, they were small enough to move around in their tubes. They could even turn around. There were other unanticipated complications as well. Overall, the dosimetry had improved, but there were still some major uncertainties.

Motorola engineers were stung by the criticisms of their Ferris wheel. So much so that in 2006, four years after the Kuchel-Utteridge paper appeared in print, they published a new **assessment** of the wheel, maintaining that it did have the desired accuracy. Few were convinced. Motorola had used cadavers for their simulations instead of live mice. The carcasses had to be thawed out the night before the experiments. Dead mice, of course, can't spin around in the Ferris wheel exposure tubes.

All this post-hoc analysis was academic because the Australian wheel would have to be completely redesigned before it would be used again.

*For a detailed review of the Kuchel-Utteridge study, see ***MWN, S/O02***.

From One Ferris Wheel to Another — PERFORM A

Motorola had hedged its bets and not staked everything on the Kuchel-Utteridge replication effort. Soon after the Repacholi results were made public, Mays Swicord, the company's head of biological research, started working on a new round of animal studies. These would make up the PERFORM A project.

Research on cell-phone cancer risks got started in 1993 after a Florida businessman alleged on CNN's widely watched Larry King show that his wife had died of a brain tumor following extensive use of a handheld phone. The U.S. Cellular Telecommunications Industry Association (**CTIA**) promised a $25 million health research effort and put George Carlo in charge. Carlo, an epidemiologist and lawyer by training, had previously helped industry ward off regulations on tobacco smoke and dioxin. The Carlo strategy was to delay: He held meetings, he did literature reviews and stroked government officials—but he sponsored only a very small number of scientific studies.

By 1998, the money was almost gone and Carlo had practically nothing to show for it. But by then, most Americans no longer cared. Their love affair with cell phones was now in full bloom and fears over brain cancer had subsided. Not so in Europe, where activists wanted to see some real science and pressured their politicians for action.

Motorola had a plan. That June, it took the first step by helping establish the Mobile Manufacturers Forum (**MMF**) with a principal objective of doing the health studies that Carlo was supposed to have done. Alcatel, Ericsson, Mitsubishi and Nokia joined Motorola as MMF's founding members. Swicord became MMF's research coordinator, the same role he was playing at Motorola.

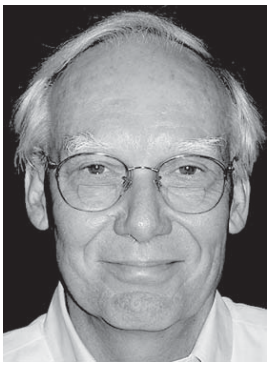
The Motorola–MMF game plan was to give the industry research initiative all the trappings of an independent project. They recruited some of the principal players in the EMF health community to decide which studies to do and who would do them. Alasdair McKinlay, who ran the U.K. government's EMF program, and also served as the vice-chairman of the International Commission on Non-Ionizing Radiation and Protection (**ICNIRP**), headed the MMF's research planning committee. McKinlay had, just the year before, chaired a panel that had performed essentially the same task for the European Commission (EC).

By December, MMF had a list of priorities in hand. At the top was a multi-country epidemiological study of cell-

phone users. Elisabeth Cardis, at the International Agency for Research on Cancer (IARC), was already working on this and preferred to limit the industry's involvement in what would be the **Interphone study**. Second on the list was a set of six animal studies—the PERFORM A project. The MMF placed ads in a number of scientific journals seeking laboratories qualified to perform these animal studies.

The MMF then asked Repacholi and his EMF project at the WHO in Geneva to review the qualifications of the applicants. Though few were aware of it at the time, the cell-phone industry was one of Repacholi's largest financial supporters. Repacholi, in turn, put Chris Portier of the U.S. National Institute of Environmental Health Sciences (**NIEHS**) in charge of the panel assessing the labs. Portier was the head of the NIEHS' Environmental Toxicology Program. PERFORM A now had the right cast of players to appear as if it was something other than an industry-sponsored project.

Another key part of the plan was to make sure that radiation exposures were done as precisely as possible. For this, Motorola and the MMF recruited Niels Kuster in Zurich. Kuster, an ambitious young microwave researcher, was a protégé of Balzano's. He had helped Ross Adey with his carousel exposures and had even spent a sabbatical at Motorola's research lab in Fort Lauderdale. With the assistance of other cell-phone companies, Balzano had raised money for Kuster to launch the Foundation for Research on Information Technology in Society (**IT'IS**). Kuster became the director of the foundation and Balzano a member of the board. Though Balzano retired from Motorola in 2001, he continues to be a director of IT'IS, as is Mike Milligan, the secretary-general of the MMF.



Mays Swicord: The force behind PERFORM A

The MMF pledged not only to help sponsor the PERFORM A experiments—the MMF and the **GSM Association**, another industry trade group, would end up providing more than half the cost of the project—but also to supply the exposure systems and to help improve the dosimetry. Kuster and IT'IS would fulfill that commitment.

The last step was the funding. The EC had set aside a large pot of money for research under what was known as the **Fifth Framework Program**. The budget for work on environment and health alone was €160 million* and the EC had, for once, included electromagnetic radiation among the usual priority issues—such as climate change. The MMF succeeded in getting just over €2 million for PERFORM A. The MMF, together with the GSM Association, contributed €4.25 million, more than half of the €8 million budget. The balance of the money came from sources in Austria, Italy and Switzerland.

PERFORM A received the smallest EC contribution of all the other EMF projects funded under the Fifth Framework—it covered only 25% of the total budget. The European part of the Interphone study, in contrast, got the majority of its budget from the EC. Yet PERFORM A took on the aura of an EC project. Funding acknowledgements in papers from the project always put the EC at the top of the list of PERFORM A sponsors. Motorola and the MMF had succeeded in turning their initiative into what appeared to be an official government project.

The MMF and Motorola selected the Ferris wheel for the six animal experiments, but the deficiencies in the Australian wheel had to be corrected before it could be used again. Kuster's team at IT'IS made a number of modifications to the mouse wheel, including adding a second set of smaller tubes to make sure young mice could no longer turn around as they had in the Australian experiment. They increased the capacity of the wheel from 40 to 65 mice, making it even more cost-efficient. A rat wheel, which could accommodate 17 rats, was also designed and built.

At IT'IS, the operating premise was that putting the animals in tubes inside the wheel would not cause undue stress. They assumed that if there were any stress, the rats and mice would soon get over it. With a little training, the animals would be quick to take up their positions in the tubes and stay still while receiving the radiation. And since rodents are nocturnal creatures, they might well sleep through their daytime exposures.

Restraining the animals in tubes is an accepted and commonly used procedure in animal inhalation studies, Kuster told *Microwave News*. He said that there was never any expectation that the cage controls would turn out the same way as those that had spent time in the Ferris wheel. But those changes would be inconsequential. "I was assured by the biologists that, whatever the expected differences due to daily handling, restraining and food consumption, they would not cause a problem in interpreting the experimental results," Kuster said.

Jürg Fröhlich, an IT'IS alumnus who was responsible for the numerical dosimetry of the wheels, recalls the tre-

* In 2000, the euro had approximate parity with the dollar; at the end of 2007, it is closing in on $1.50.

mendous pressure to finish building the wheels so that the PERFORM A experiments could begin. "We were working nearly around the clock," he said, "and when we stopped to ask whether the restraints could affect the animals, the PERFORM A biologists assured us that for mice a two-hour—or for rats a four-hour—exposure in the wheel would not cause any stress." In a telephone interview from the ETH Zurich where he now works, Fröhlich said that the IT'IS engineers were told to "leave the biology to the biologists."

PERFORM A's First Experimental Finding: Mice in the Ferris Wheel Are Under Stress

No one doubts that stress of one kind or another can have a profound impact on mice and rats. Thirty years ago, Benjamin Newberry found that restraint stress could modulate the growth of chemically induced tumors in rats. In 1982, Stan Szmigielski of the Center for Radiobiology and Radioprotection in Warsaw ran a similar **experiment** with mice and benzopyrene, a cancer-causing chemical found in cigarette smoke. Szmigielski painted the skin of the mice with benzopyrene and then subjected them to chronic confinement. While Newberry had seen slower tumor growth, Szmigielski saw enhanced tumor development. Though the two results might seem inconsistent, each had used different rodents, different types of restraint stress and different chemicals that caused different types of cancer. Once again, stress could be beneficial at times and detrimental at other times —it all depends on the specific conditions.

Szmigielski's main interest was to find out whether microwaves could promote cancer—the same as PERFORM A's. When Szmigielski exposed the benzopyrene-painted mice to relatively low levels of radiation, he found that the microwaves, like confinement stress, accelerated the growth of tumors. If animals were exposed to stress and microwaves at the same time, the effect of one would be indistinguishable from that of the other.

In Szmigielski's experiments, stress and microwaves had similar effects on the tumors. Both promoted cancer. A few years later, Henry Lai, C.K. Chou and Bill Guy of the University of Washington, Seattle, **compared** how stress and microwaves influenced the activity of a number of psychoactive drugs. They too found that, in general, both had similar effects. "Microwaves act as a general stressor," Lai told us recently.

Microwave experiments, like all others, need exposed animals, shams *and* cage controls. Back in 1980, Sol Michaelson and Greg Lotz of the University of Rochester cautioned that possible stress from microwaves has "to be isolated from extraneous factors that are usually associated with experimental procedures." It's no different today. "Everybody knows cage controls are important," said Jim Lin, of the University of Illinois-Chicago, the editor-in-chief of *Bioelectromagnetics*. "It's one of the axioms of animal research." When the Kuchel-Utteridge paper came out, Lin, who writes a regular column for a number of engineering magazines, criticized the Australians for not reporting the cage-control data. Here's what he wrote in December 2002:

> Restraining the animal in a tight tube during the exposure session constitutes a continuing stress to the animal, which may lead to significant stress responses that potentially could obscure any effect from the cell-phone radiation.

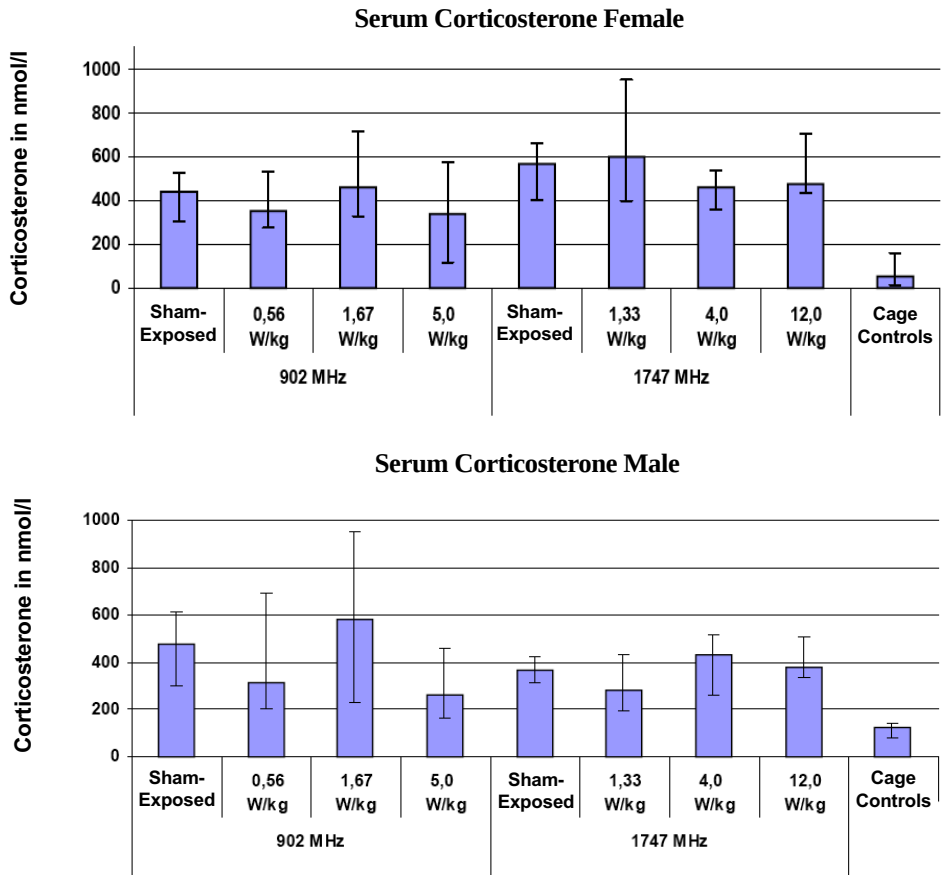
The protocols for PERFORM A specified that each of the original six experiments would include cage controls. Even the pilot studies had cage controls. When the project got underway, Clemens Dasenbrock, a veterinarian who was in charge of two of the three mouse studies at the Fraunhofer Institute for Toxicology and Experimental Medicine (known as **ITEM**) in Hannover, Germany, and who was also the overall coordinator of PERFORM A, assigned one of his graduate students, Manfred Kamlage, the task of checking out the effects of the radiation and the exposure system on the mice. Kamlage's **results** should have been startling. After only four weeks inside the Ferris wheel's tubes (for two hours a day), the male sham-exposed mice had four times the levels of corticosterone, a stress hormone, in their blood compared with cage controls. For the females, the difference was even larger—close to five times more than the cage controls (see bar graphs on p.9). The mice had even been trained to go into the Ferris wheel's tubes for five weeks before the experiment began, and they still felt stress. The odds that this finding could have happened by chance are more than a thousand to one, according to Kamlage.

Dasenbrock presented his student's findings at a meeting of the PERFORM A management committee in Janu-

ary 2002. The members of the committee included the principals of all six studies, as well as IT'IS' Kuster. Also present were Indrek Tammeaid of the University of Helsinki, who served as the liaison to the MMF and GSM Association, the cell-phone industry sponsors, and the project's two external advisors, Larry Anderson, an American who was finishing up his own animal study for Motorola at the **Battelle Pacific Labs**, and Victor Feron of the **TNO**, a Dutch research outfit. Dasenbrock told them that Kamlage had "clearly" demonstrated that a two-hour restraint "highly stressed the animals," according to the minutes of the meeting obtained by *Microwave News*.

"Tube restraint stress is not unexpected," noted Feron, in his own report on the meeting. He called Kamlage's observation "highly relevant." Yet, there is no indication that anyone present suggested that restraint stress might confound the three mice studies that were already underway. Nor that anyone raised the possibility of delaying the rat studies, which were slated to begin soon afterwards, to allow time to reconsider the stress reaction. Far from it—Feron made light of Kamlage's finding. "Stressed ... exposed mice may even better simulate exposure conditions (the use of mobile phones) than relaxed ... exposed mice!!" he quipped.

One person who was concerned was Wolfgang Löscher, the head of the Department of Pharmacology, Toxicology



Kamlage's experimental findings showing the levels of stress hormones in male and female mice (at 902 MHz and 1747 MHz). Note the difference between the cage controls, on one hand, and the shams and radiation-exposed mice on the other. Note also the difference in responses between males and females (adapted from p.111 of Kamlage's thesis).

and Pharmacy at the University of Veterinary Medicine, which like ITEM, is in Hannover. Löscher was a member of Kamlage's thesis committee and, on seeing his data, questioned Dasenbrock as to whether microwave effects could be detected in an experiment using the Motorola Ferris wheel.

"The exposure system induced a massive stress response in the animals," Löscher told us in a telephone interview. "The PERFORM A group claimed that the mice would adapt to the stress, but I had my doubts because they did not demonstrate any adaptation in Kamlage's experiment."

PERFORM A is not the only animal project to have run into problems. Look what happened to Alexander Lerchl of the Jacobs University of Bremen, Germany. Lerchl is an avowed critic of using restrained animals. It is "common knowledge among biologists" that stress can cause a lot of changes, including altering hormone levels that can influence malignant tissue, he told us in 2002, after the Australian wheel study came out. Not surprisingly, when the German office of radiation protection commissioned Lerchl to do two cancer studies, he used free-roaming animals.

In one study, Lerchl set aside 30 mice as cage controls. But they were given different cages from the other mice. The cage controls "had to work harder for their food," Lerchl explained in a recent **paper**. In this study, the cage controls, not the shams, were under stress. They were lighter and had lower cancer rates than either the shams or the exposed mice. In one sense, this was the same outcome as in the wheel studies: The stressed animals had fewer tumors. Quite by accident, Lerchl had come up with independent support that restraint stress had confounded the PERFORM A experiments.

Dasenbrock left ITEM to join Boehringer-Ingelheim, a large drug company, in September 2004. Jochen Buschmann, a biologist, became the PERFORM A coordinator, and Thomas Tillmann took over the two mouse studies. Dasenbrock did not respond to requests for an interview. For his part, Buschmann rejected the idea that restraint stress could have confounded the mice studies. "The discussion about the pros and cons of restraint versus free moving animals is an old debate," he told *Microwave News* in an October e-mail. "I do not want to start it here again, since there are no new facts on the table."

In their **paper** reporting the results of their mouse studies, published in the April 2007 issue of *Bioelectromagnetics,* Dasenbrock and Tillman made reference to Kamlage's thesis but made no mention of the elevated stress hormones he had seen in the pilot study—nor did Buschmann cite this in the PERFORM A final report. But tube restraint was certainly on their minds, because they did refer to the work on stress by Firdaus Dhabhar and Bruce McEwen of Rockefeller University.

The most stunning disclosure in the Dasenbrock-Tillman paper was that they had not carried out complete histopathological examinations of the cage controls. They had not been checked for tumors, as had the sham and exposed mice. The PERFORM A management committee made that decision, Buschmann told us. What role Dasenbrock may have played is not known, but, in a **presentation** at a **scientific conference** a few months after his and Tillmann's mouse paper had been sent to *Bioelectromagnetics,* Dasenbrock cited the lack of histopathology on the cage controls as the studies' biggest weakness.

Löscher said that he was surprised by the decision not to examine the cage controls, especially given the stress response found in Kamlage's pre-study. So was Ron Melnick, a senior toxicologist at the NIEHS and the National Toxicology Program (NTP), whose own long-term cellphone radiation studies will begin in early 2008. "If you see a difference between cage controls and shams, you would do the histopathology on the cage controls," he said in a telephone interview from his office in North Carolina. "That's the whole point of cage controls—to look at them."

PERFORM A: The Results

If you read only the abstracts of the six PERFORM A studies —the truth is that most people, including many scientists, never read beyond the abstract—you would quickly conclude that no one had found any evidence of a cancer risk in rats and mice. There were a few anomalies, but these were discounted. The unambiguous message is that cell phones do not cause or promote cancer in animals.

You would probably reach the same conclusion if you were conscientious enough to read further. Take, for instance, the following summary from the **paper** on the two-year rat studies at Switzerland's RCC Ltd led by Paul Smith:

> These two-year bioassay studies, which were conducted under stringent conditions according to international testing guidelines involving three exposure levels, group sizes giving ample statistical power, detailed dosimetric assessment, GLP conditions, and double-blinding, produced no evidence that RF-field exposure had any effect on the incidence or severity of any non-neoplastic [non-tumor] condition or the type, incidence, multiplicity and latency of any neoplastic lesion [tumor].

It could hardly sound more definitive.

The same, "no cancer risk" message was put forward at scientific meetings. Last April, a session was devoted to PERFORM A at the European Bioelectromagnetics Association conference in Bordeaux, where all the labs presented their results for the first time. Buschmann closed the program by asking, "What does this set of valid studies tell us?" His answer, according to one detailed account: "I would say, if [cell-phone radiation] were a chemical, there would be no need to classify this as a carcinogen."

Even those not directly connected to PERFORM A are telling the same story. At a workshop in Paris in October, Isabelle Lagroye, of Bernard Veyret's group at the University of Bordeaux, summarized the project results and gave the same unambiguous message: The PERFORM A animal studies show no evidence of any type of cancer-causing effect.

What is striking is what is left unsaid: The consistent divergence between the cage controls and the shams across all six sets of PERFORM A results, as well as those in the add-on Chinese study (see the **blue** bold numbers in the "CC" and "S" columns under tumor incidence in the table on p.14). These differences make the no-cancer picture a lot hazier. To be sure, there are variations in rates among the males and females, and for benign and malignant tumors, but scanning down the columns in the table, it's hard to escape the conclusion that the exposure system had an effect on the sham-exposed animals.

Switzerland's Paul Smith, who wrote so persuasively that his rat studies had found no adverse effects, in fact also saw a large difference in palpable masses between the shams and the cage controls—up to five times as many in the males. But for the females, the numbers are reversed, more masses in the shams than in the cage controls. Smith tries to finesse this by averaging the masses in the males and females—combine an unusually high number with an oddly low number and you can get a normal average number. It could be an example straight out of the classic text, ***How To Lie with Statistics.***

What Smith and the PERFORM A final report fail to point out is that the higher incidence among his female shams is unique across all seven experiments. This could well have been an interesting line of inquiry, especially since Kamlage, Dasenbrock's student, had shown that male and female mice had different responses to restraint stress. Other than palpating the rats, Smith also did not do histopathological examinations of the cage controls.

Those who have read the PERFORM A papers believe that they show that confinement stress overloaded the animals' response system. "The difference between shams and cage controls is a showstopper," Henry Lai told *Microwave News.* " They are so different, you cannot conclude anything about cancer risks." Lai, a research professor at the University of Washington, has been working on microwave health effects for close to 30 years.

Michael Kundi, the head of the Institute of Environmental Health at the Medical University of Vienna, also sees restraint stress as a confounder. "In my opinion, the differences between the shams and cage controls could be due to a combination of stress due to the handling of the animals, the animals' confinement within the wheel and the sleep disruption induced by the daytime exposure when they are usually asleep," he said. After a careful review of all the results, Kundi sees indications that cell-phone radiation could in fact pose a cancer risk.

"Yes, it's data but, from my standpoint, it doesn't answer the cancer question adequately," said NIEHS' Melnick. "If I was sure there were no effects, we would not be going forward with our own study." The cell-phone study is the largest ever done by the NTP. Melnick, like Lai, Löscher and Kundi, has concerns that constraining animals might have affected the outcome of the study.

Löscher, who was first concerned about the Ferris wheel exposure system five years ago after seeing Kamlage's study results, now has no more doubts that the animals were under stress inside the tubes. "When I saw the results of the PERFORM A studies, I knew that my concerns about the exposure system were justified," Löscher told us.

What Went Wrong

The PERFORM A experiments cost about $10 million and, if the critics are right, most of that money went down the drain. How could it have gone so wrong? Restraint stress is not a new concept—there is ample evidence that it was on everybody's mind from the very beginning of the project.

Everywhere you turn, from Benjamin Newberry's DMBA study in the 1970's to Stan Szmigielski's benzopyrene experiment in the 1980's and the Dhabar-McEwen and Ross Adey tube studies in the 1990's, there were clear signs that restraining animals caused stress. It is inconceivable that the PERFORM A team was unaware of the problem. In fact, Ron Melnick recalls that when he went to Geneva in November 2000 as part of an NIEHS delegation to learn about the project, restraint stress came up at the meeting.

Meike Mevissen, a professor of veterinary pharmacology and toxicology at the University of Berne, said that she too raised possible confounding due to restraint stress on a number of occasions at conferences and workshops. "The reply was always the same: The biologists say it's okay," she said. "They were always more concerned about getting precise exposures than in what the restraints might do to the animals." Mevissen is a member of the scientific committee of the **Swiss Research Foundation on Mobile Communications**.

Far more disturbing is that Dasenbrock and Buschmann, the PERFORM A coordinators, appear to have tried to cover up Kamlage's finding that the Ferris wheel puts the mice under stress. The **thesis** has never been published, and these results are not mentioned in any of the PERFORM A reports and papers. It might have remained hidden from view on some dusty bookshelf, except that the university is now posting student dissertations on the Internet.

Why would they risk screwing up their own research project by ignoring experimental evidence that restraint stress was affecting Kamlage's animals? Our best guess is that they saw their job—just as the other principal investigators saw theirs— as having one simple objective: To please the client, the cell-phone industry. The way to do that was to get the experiments done and to get them done on time and on budget. PERFORM A was not scientific research, but contract research. There was no money to deal with complications like the fact that the exposure system provided by Motorola was unsuitable and had to be replaced.

Kuster's team at IT'IS ran over budget by €200,000 redesigning and building the Ferris wheels. Yet, the MMF and GSM Association balked at reimbursing him for the extra money he had spent. "[Kuster] must insist on the … additional €200,000," the PERFORM A managers agreed in January 2002, according to the minutes of their meeting. The take-home lesson—Don't work too hard because your extra effort and expenses will not be rewarded or recouped—could not have escaped everyone's notice.

The MMF and GSM Association also wanted to save money by eliminating the project's two advisers, Larry Anderson and Victor Feron. "It would be a shame if the externals must leave in the middle of the project," the minutes state. At the meeting, more time was devoted to financial issues than to Kamlage's findings that the mice were experiencing restraint stress in the Ferris wheel.

To satisfy concerns that the project be protected from industry influence, there was what they called a "firewall" between the researchers and the sponsors. Indrek Tammeaid of the University of Helsinki was hired to play this role. How much information he passed back to the MMF and GSM Association—for instance, the minutes of all the management meetings—is not known, but there are indications that the industry was better informed on what was going on in the project than any outsiders. Our dealings with Tammeaid suggest that he also served as a firewall to shield the industry. In an extended exchange of e-mails with *Microwave News*, Tammeaid refused to say how much money the MMF and GSM Association had contributed to PERFORM A, even though this number has previously been made public and is available on the **Internet**—it's €4.25 million.

How do we explain Dasenbrock and Tillmann's decision not to do a complete histopagthological examination of the cage controls? There are two possibilities. The first is that this was another way to save money. Tillmann told us that it would cost on the order of $100,000 to do a detailed examination of the 100 cage-control mice. That might sound like a lot of money, but it is only 1% of the total PERFORM A budget. An alternative explanation is that

they knew there was a good chance that the histopathology would show that the wheel had confounded their study and they would rather not generate more evidence that using the wheel had been a big mistake.

The case for a cover-up is supported not only by the attempt to bury the Kamlage pre-study, but also by the fact that *not one* of the PERFORM A papers cites the two papers on microwave exposures that point to the confounding influence of restraint stress: the one by Ross Adey and the other by Stan Szmigielski. Adey's work on the stress brought on by exposing the animals in restraining tubes was sponsored by the same people at Motorola who were helping pay for the PERFORM A studies. It came out in 2001 when the project was just getting underway. It is hard to believe that Dasenbrock and the others were unaware of it. More likely, it was a case of maybe if we don't talk about stress, no one will bring it up.

The same applies to Szmigielski's 1982 paper showing that confinement stress and microwaves have similar effects. Though published 25 years ago, it is hardly an obscure piece of work. The European PERFORM A labs did not take it into account, but the Chinese cited it in their DMBA rat paper—as did research groups in Finland, France and Germany, all of which have published studies on the effects of cell-phone radiation on animals. Szmigielski is a well-known, long-standing member of the electromagnetic research community. He and Henry Lai, another well-known player, have systematically compared the effects of stress with those of microwave radiation, yet this work was ignored.

It is hard to escape the conclusion that everyone connected with the project was trying to please the cell-phone clients, business-as-usual for consultants.

Mays Swicord, the chief architect of PERFORM A, never had any doubt about its outcome. Only a year after some of the animal studies had gotten under way—long before anyone could have any idea what they would show—Swicord began beating the drum to put an end to any further health research. In an interview with the ***New Scientist*** in 2003, Swicord said that the reason no health effects from cell-phone radiation have been found is that there simply aren't any and that doing any more research would be a waste of money. Swicord did not even attempt to project scientific objectivity.

Happily, two new large-scale animal studies are under way: one at the **European Foundation for Oncology and Environmental Sciences** in Bologna, Italy, under the direction of **Morando Soffritti**. The other, which is being supervised by NIEHS' Ron Melnick at the National Toxicology Program, will begin early next year at IITRI in Chicago. Both are using unrestrained animals.

The projects have the added advantage of exposing rats and mice for longer than the one to four hours a day used in the PERFORM A studies—many people use their phones longer than that. This was another major weakness of the Ferris wheel studies, as well as many of the carousel studies, according to both Soffritti and Melnick. Soffritti's exposures are lasting 19 hours a day, and Melnick's up to 20 hours a day.

For the exposures, Melnick is using reverberation chambers—think of them as giant microwave ovens that can hold 100 rats or 200 mice, each in its own cage. Once again, IT'IS' Kuster supplied the exposure chambers. They were built in Switzerland and shipped to Chicago. Kuster estimates that if PERFORM A had used free-roaming animals, the costs would have been more than four times higher—not counting the costs of integrating the chambers in existing facilities, in itself a considerable expense. The NTP project has a budget of $22 million.

Soffritti will have his results in 2010 and Melnick his in 2011, but there's no guarantee that either will give us any definitive answers about the safety of cell phones. Even if nothing goes wrong, some major uncertainties will remain. First, the radiation exposures, like those in PERFORM A, will be in the far field. No one yet knows whether it makes sense to extrapolate animal data from far-field exposures to actual cell-phone exposures, which are in the near field. Also up in the air is whether the type of radiation used in the experiments adequately simulates the radiation from an operating cell phone. This is a very complicated question and applies to all animal studies, not just those in PERFORM A.

More likely, we will have to rely on epidemiological studies. These are also hard to do, but they have the advantage of looking at real people using actual cell phones.

The Motorola Ferris wheel turns out to have been a triumph of engineering over biology. It is a cost-effective exposure system, but it puts too much stress on the animals. The PERFORM A project might have provided us with some useful data if only the biologists had spoken up.

But the most important lesson is that a complex scientific question cannot be answered on the cheap and certainly not by sponsors that believe the experiments were not worth doing in the first place.

Cell Phone Animal Studies (1997 - 2007)

WHEELS (PERFORM A)

Principal Authors	Reference	Animal	Exposure: Frequency Modulation (Carcinogen)	Exposure System‡ Dose (W/Kg)*	Weight (g) CC	S	E	Tumor Incidence** (%) CC	S	E	Sponsor†
T. Utteridge T. Kuchel (Australia)	*Radiation Research* ***158,* 357, 2002** ***159,* 276, 2003**	Mice *Pim1* (transgenic: lymphoma-prone)	898.4 MHz GSM far-field	Mouse Wheel #1 0.25,1,2,4 1h/d,5d/w,24m	CC Weights Not Given			Lymphoma[a] **80**	**75**	73,72,78,84 All Tumors **85**	**79**	82,74,81,85	NHMRC ARPANSA Motorola
D. Yu H. Chiang (China)	*Radiation Research* ***165,* 174, 2006**	Rats (f) Sprague Dawley	900 MHz GSM (with DMBA) far-field	Rat Wheel 0.44,1.33,4 4h/d,5d/w,6m	CC 10% Heavier Than S and E A Statistically Significant Difference			Palpable Masses[§] **41**	**19**	28,27,32 Mammary Tumors **All:** **60**	**45**	37,41,43 **B**f: **23** **8** 13,7,5 **M**f: **37** **37** 25,34,38	GSMA MMF (PERFORM A follow-up)
T. Tillmann C. Dasenbrock (Germany)	*Bioelectromagnetics* ***28,* 173, 2007**	Mice B6C3F1	1. 902 MHz GSM 2. 1747 MHz DCS both far-field	Mouse Wheel #2 0.4,1.3,4 2h/d,5d/w,24m	CAGE CONTROL ANIMALS NOT EXAMINED						PERFORM A EC, GSMA, MMF
G. Oberto S. Tofani (Italy)	*Radiation Research* ***168,* 316, 2007**	Mice *Pim1* (transgenic: lymphoma-prone)	900 MHz GSM far-field	Mouse Wheel #2 0.5,1.4,4 1h/d,7d/w,18m	CC 10% Heavier Than S and E			Lymphoma m: **16**	**18**	20.20,6 f: **52** **44** 36,60,40 All Tumors **B**m: **26** **6** 8,12,24 **B**f: **42** **24** 32,30,30 **M**m: **28** **26** 26,22,12 **M**f: **70** **54** 58,68,46			PERFORM A EC, GSMA, MMF
P. Smith (Switzerland)	*Radiation Research* ***168,* 480, 2007**	Rats Wistar	1. 902 MHz GSM 2. 1747 MHz DCS both far-field	Rat Wheel 0.44,1.33,4 2h/d,5d/w,24m	CC Weight: "Considerably Greater" Than S and E Exact Numbers Not Available			Palpable Masses 1. GSM m: **20**	**6**	16,4,18 f: **28** **40** 34,36,30 2. DCS m: **20** **4** 16,10,20 f: **28** **42** 24,30,32 NO HISTOPATHOLOGY FOR CAGE CONTROLS			PERFORM A EC, GSMA, MMF
R. Hruby (Austria)	Presented at the 8th meeting of the *European Bioelectromagnetics Association* (EBEA), April 2007 (**in press, *Mutation Research***)	Rats (f) Sprague Dawley	902 MHz GSM (with DMBA) far-field	Rat Wheel 0.4,1.3.4 4h/d,5d/w,6m	"No Differences" Between CC and S			Palpable Masses[§] **43**	**19**	33,26,33 Mammary Tumors **All:** **73**	**60**	57,50,65 **B**f: **28** **30** 17,15,18 **M**f: **45** **30** 40,35,47	PERFORM A EC, GSMA, MMF

UNRESTRAINED and PARTIALLY RESTRAINED

Principal Authors	Reference	Animal [number/cage]	Exposure: Frequency Modulation (Carcinogen)	Exposure System‡ Dose (W/Kg)*	Weight (g) CC	Weight (g) S	Weight (g) E	Tumor Incidence** (%) CC	Tumor Incidence** (%) S	Tumor Incidence** (%) E	Sponsor†
M. Repacholi (Australia)	*Radiation Research* **147, 631, 1997**	Mice (f) *Pim1 (transgenic* lymphoma-prone) [5]	900 MHz GSM far-field	Unrestrained 0.008-4.2 0.13-1.4 (average) 2x0.5h/d,18m	———	NO CAGE CONTROLS	———				NHMRC Telstra, Ltd.
P. Heikkinen J. Juutilainen (Finland)	*Radiation Research* **156, 775, 2001**	Mice CBA/S [6-7]	902.5 MHz NMT[¥] 902.4 MHz GSM (with X-ray) far-field	Partial Restraint NMT:1.5 GSM:0.35 up to±30% 1.5h/d,5d/w,18m	S (with X-Rays) Lighter than CC			No Sham/Sham Group Shams Were Exposed to X-Rays			TEKES, FGF Benefon, Finnish Work Environment Fund Elisa Com., Nokia, Sonera
H. Bartsch C. Bartsch (Germany)	*Radiation Research* **157, 183, 2002**	Rats Sprague-Dawley [12]	900 MHz GSM (with DMBA) far-field	Unrestrained 0.0175-0.07 (0.08 for young) continuous[ƒ], 8-11m	———	NO CAGE CONTROLS (3 experiments carried out over 3 successive years)	———				Deutsche Telekom
P. Heikkinen J. Juutilainen (Finland)	*International Journal of Radiation Biology* **79, 221, 2003**	Mice transgenic and non-transgenic [6-7]	849 MHz DAMPS (pulsed at 50 Hz) 902 MHz GSM (with UV) far-field	Partial Restraint both 0.5 ±30% for adults 1.5h/d,5d/w,12m	S (with UV) Lighter than CC			No Sham/Sham Group Shams Were Exposed to UV Radiation			TEKES, Benefon Elisa Com Nokia, Sonera
R. Anane B. Veyret (France)	*Radiation Research* **160, 492, 2003**	Rats Sprague-Dawley [8/cage; 1/compartment]	900 MHz GSM (with DMBA) far-field	Partial Restraint 1. 1.4,2.2,3.5 2. 0.1,0.7,1.4 ±0.2 2h/d,5d/w,9w	———	8 CAGE CONTROL RATS ONLY NO CAGE CONTROL DATA PRESENTED	———				CNRS France Telecom Aquitaine Research Council
A. Sommer A. Lerchl (Germany)	*BMC Cancer* **4, 77, 2004**	Mice AKR/J [6-7]	900 MHz GSM far-field	Unrestrained 0.4 ±40% continuous[ƒ], life	———	NO CAGE CONTROLS	———				BfS
P. Heikkinen J. Juutilainen (Finland)	*Radiation Research* **166, 397, 2006** (see also *Radiation Research* **165, 598, 2006**)	Rats (f) Wistar [3]	900 MHz GSM (with MX) far-field	Unrestrained 0.3 (0.07-1.2) 0.9 (0.21-3.6) 2h/d,5d/w,24m	S (with MX) 5% Heavier than CC			No Sham/Sham Group Shams Were Given MX, a Known Carcinogen			CEMFEC EC, Nokia
A. Sommer A. Lerchl (Germany)	*Radiation Research* **168, 72, 2007**	Mice AKR/J (lymphoma-prone) [6-7]	1.966 GHz UMTS far-field	Unrestrained 0.4 ±50% continuous[ƒ], life	CC Lighter 27.2 CCs "had to work harder for their food"		40.4	Lymphoma **96.7**	**93.1**	88.1	BfS

CAROUSELS

Principal Authors	Reference	Animal [number/ carousel]	Exposure: Frequency Modulation (Carcinogen)	Exposure System‡ Dose (W/Kg)*	Weight (g) CC	S	E	Tumor Incidence** (%) CC	S	E	Sponsor
W.R. Adey (U.S.)	*Radiation Research* **152, 293, 1999**	Rats Fischer344 [10]	836 MHz TDMA (with ENU) near-field¶	0.33-0.53 ±25% in brain 2h/d,4d/w,24m	———	NO CAGE CONTROLS		———			Motorola
W.R. Adey (U.S.)	*Cancer Research* **60, 1857, 2000**	Rats Fischer344 [10]	836.55 MHz FM (with ENU) near-field¶	1.0-1.2 in brain 2h/d,4d/w,24m	Not Given			Central Nervous System Tumors ENU **14** non-ENU **4**	**22** **1**	18 4	Motorola
B. Zook (U.S.)	*Radiation Research* **155, 572, 2001**	Rats Sprague Dawley [10]	860 MHz CW and Pulsed (both with ENU) near-field	0.27-0.42 1.0 ±0.2 in brain 6h/d,5d/w,22m	CC Heavier Exact Numbers Not Available			Brain Tumors 0 ENU **10** 2.5 ENU **8** 10 ENU **68**	**7** **9** **58**	CW: 5, P: 8 CW: 5, P: 13 CW: N/A, P: 60	Motorola
M. La Regina J. Roti Roti (U.S.)	*Radiation Research* **160, 143, 2003**	Rats Fischer344 [10]	835.62 MHz FDMA 847.74 MHz CDMA near-field	1.3 ±0.5 in brain 4h/d,5d/w,24m	———	NO CAGE CONTROLS		———			Motorola
L. Anderson (U.S.)	*Radiation Research* **162, 201, 2004**	Rats Fischer344 [10]	1.6 GHz Iridium near-field¶	0.16,1.6 +15%/-30% in brain 2h/d,7d/w,24m	CC Heavier Than E or S Exact Numbers Not Available	———	CAGE CONTROLS NOT EXAMINED		———		Motorola

* Whole-Body, except where noted

** CC: Cage control; S: sham; E: exposed; **B**: benign; **M**: malignant; **m**: male; **f**: female

¶ Following far-field exposure *in utero*

§ Approximate numbers; read off graph

† ARPANSA: Australian Radiation Protection and Nuclear Safety Agency; PERFORM A: project funded under the EC's 5th Framework Research Program; BfS: German Bureau for Radiation Protection; CEMFEC: project funded under the EC's 5th Framework Research Program; CNRS: Centre National de la Recherche Scientifique; FGF: Research Association for Radio Applications (Germany); GSMA: GSM Alliance; MMF: Mobile Manufacturers Forum; EC: European Commission; NHMRC: National Health and Medical Research Council; TEKES: The National Technology Agency (Finland). PERFORM A received additional funding from the Austrian and Swiss governments.

‡ In the Utteridge study, the mouse wheel (#1) could accommodate up to 40 mice. For PERFORM A, the wheel was redesigned (#2), and could hold up to 65. The rat wheel could accommodate up to 17 rats.

∂ These percentages are approximate; Utteridge and Kuchel reported different statistics at different times.

¥ Nordic Mobile Telephones (NMT): This system used CW radiation.

∫ Continuous except when animals were weighed, or palpated, and when the cages were cleaned.